METALLURGIA

THE BRITISH JOURNAL OF METALS

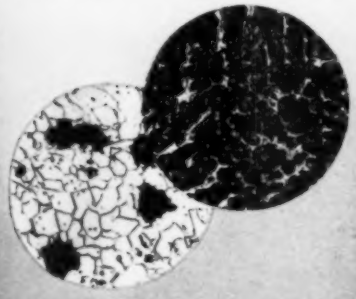
Vol. 54 No. 324 OCTOBER, 1956 Monthly: TWO SHILLINGS

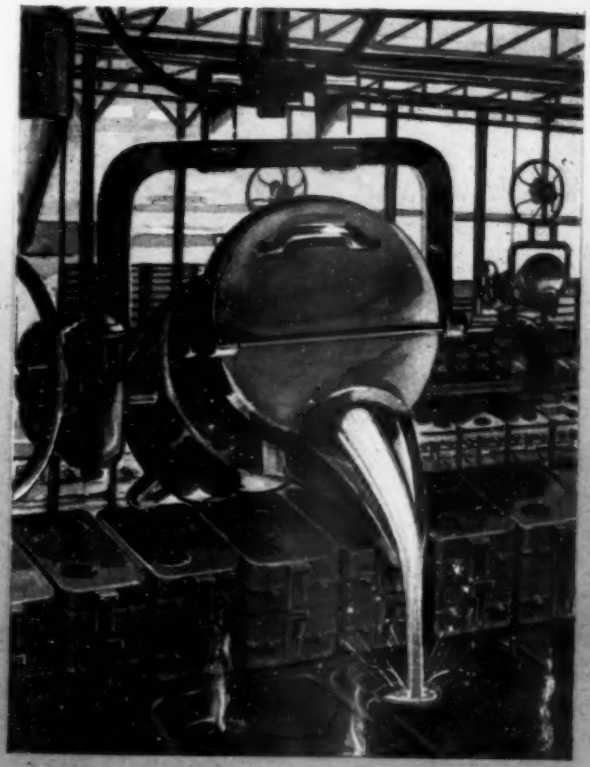
UNIVERSITY OF MICHIGAN

OCT

EAST ENGINEERING LIBRARY.

SCIENTIFICALLY CONTROLLED IN EVERY STAGE OF MANUFACTURE



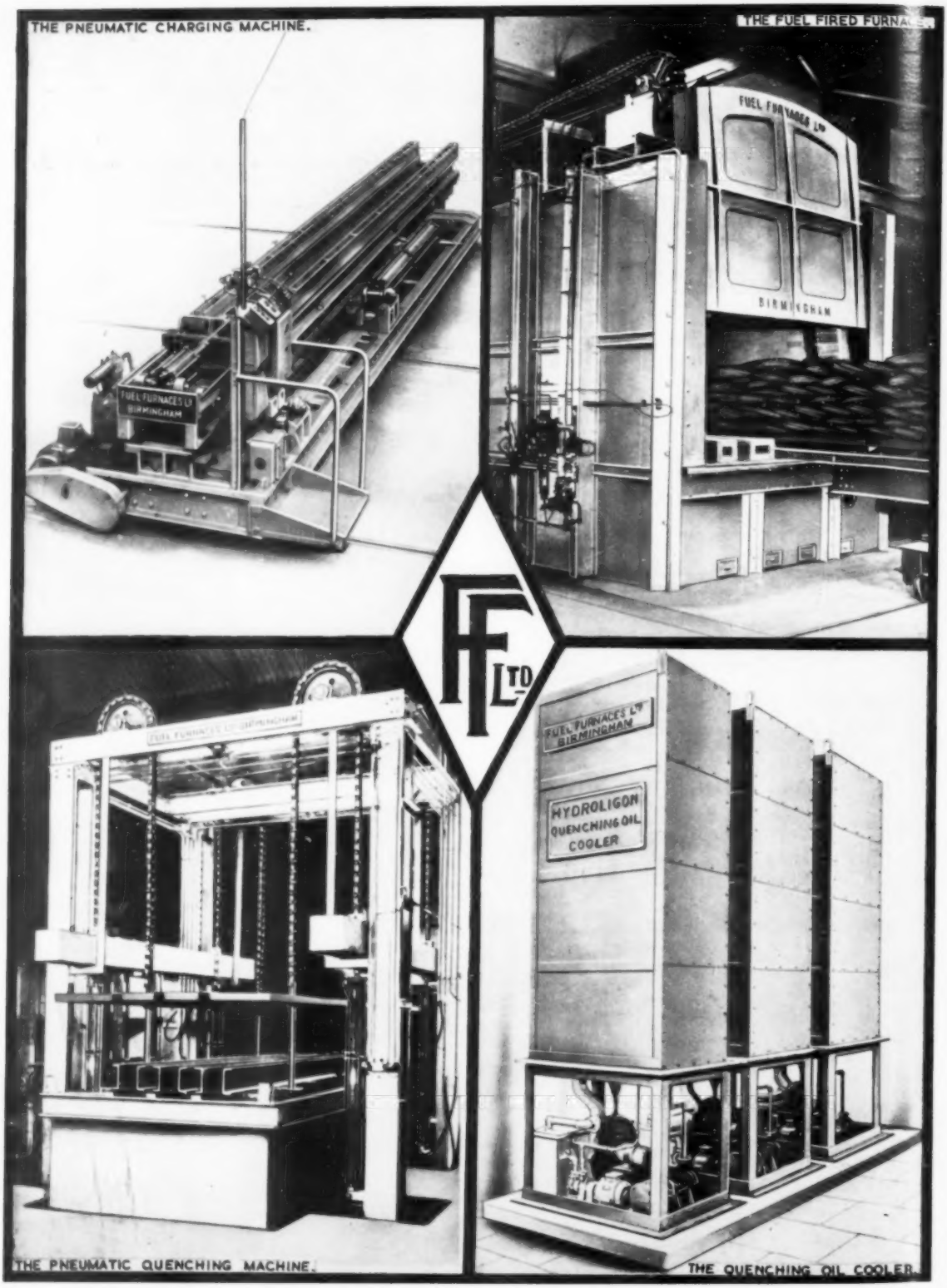


finest blackheart MALLEABLE IRON CASTINGS

Send for details of our film "Modern Malleable"

HALE & HALE [TIPTON] LIMITED DUDLEY PORT Staffs

GRAMS: HALFEO TIPTON PHONES: TIPTON 1671/5


THE PNEUMATIC CHARGING MACHINE.
FUEL FURNACES LD BIRMINGHAM
THE FUEL FIRED FURNACE.
FUEL FURNACES LTD
BIRMINGHAM
FF LTD
FUEL FURNACES LTD BIRMINGHAM
HYDROLIGON QUENCHING OIL COOLER
THE PNEUMATIC QUENCHING MACHINE.
THE QUENCHING OIL COOLER.

METALLURGIA

THE BRITISH JOURNAL OF METALS
INCORPORATING THE METALLURGICAL ENGINEER

CONTENTS FOR OCTOBER, 1956 Vol. 54 No. 324

PUBLISHED MONTHLY BY
The Kennedy Press, Ltd.,
31, King Street West,
Manchester, 3.
Telephone: BLAckfriars 2084

London Office:
50, Temple Chambers,
Temple Avenue, E.C.4.
FLEet Street 8914

CONTRIBUTIONS

Readers are invited to submit articles for publication in the editorial pages: photographs and/or drawings suitable for reproduction are especially welcome. Contributions are paid for at the usual rates. We accept no responsibility in connection with submitted manuscript. All editorial communications should be addressed to The Editor, "Metallurgia," 31, King Street West, Manchester, 3.

SUBSCRIPTIONS

Subscription Rates throughout the World—24/- per annum, Post free.

ADVERTISING

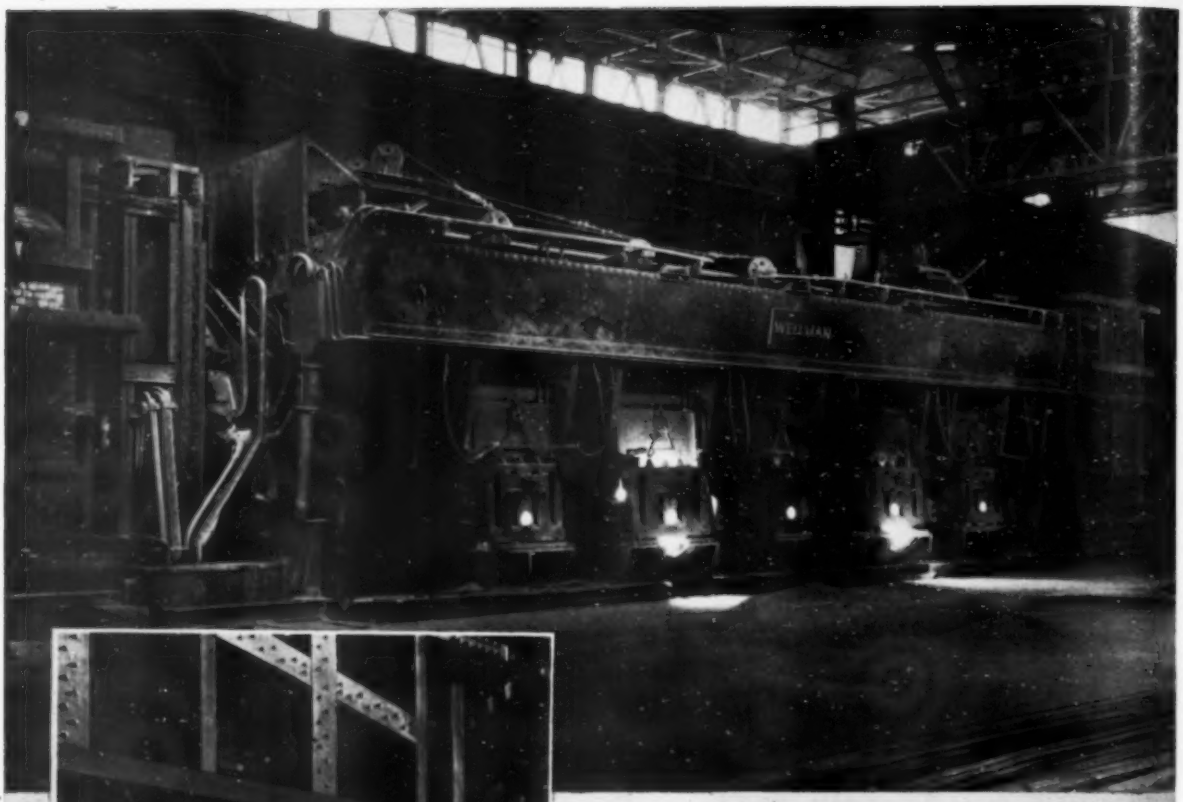
Communications and enquiries should be addressed to the Advertisement Manager at Manchester.

	Page
Plant Scale Research	159
Meeting Diary	160
Co-operative Research	161–182
The British Ceramic Research Association. By A. E. Dodd	161–162
The British Cast Iron Research Association. By J. G. Pearce	163–165
The British Iron and Steel Research Association	166–172, 182
The Equipment of the British Non-Ferrous Metals Research Association. By E. C. Mantle	173–177, 182
The British Steel Castings Research Association. By A. H. Sully	178–182
Acheson Centenary	183–186
The Fundamental Properties of Metals and Powder Metallurgy. By H. W. Greenwood	187–188
News and Announcements	189–191
Recent Developments	192–194
Current Literature	195–196

LABORATORY METHODS SUPPLEMENT

Particle Size Determination in Powder Metallurgy. A Review of Available Methods. By L. A. Phelps	197–200
The Application of the Hilger Direct Reading Attachment to the Spectrographic Analysis of Hiduminum RR.50 Type Alloy. By E. C. Mills and S. E. Hermon	201–203
The Polarographic Determination of Zinc in Aluminium Bronze. By D. R. Curry and Miss J. T. King-Cox	204–206
A Precision Universal Stage for the Microscopical Examination of Fracture Surfaces. By J. F. McNeil	207–210

The articles in this Journal are indexed in THE INDUSTRIAL ARTS INDEX



Two of four BISRA Oil Burners firing a Wellman 300/350 ton Open Hearth Furnace in a leading British Steelworks. Two further furnaces of the same capacity and also eight smaller furnaces in this Steelworks are also equipped with BISRA Oil Burners.

BISRA
OIL BURNERS

FOR OIL & OIL/GAS FIRING OF HIGH TEMPERATURE FURNACES

Increase Furnace Productivity

Lower Fuel Consumption

Ensure better Flame Control resulting in lower Furnace Refractory Maintenance Costs

Reduce Steam Requirements for the same flame conditions

Easy and Inexpensive to install

Simple in design

THE WELLMAN SMITH OWEN ENGINEERING CORPN. LTD.
PARNELL HOUSE, WILTON ROAD, LONDON, S.W.1 WORKS: DARLASTON, SOUTH STAFFS.

METALLURGIA

THE BRITISH JOURNAL OF METALS

INCORPORATING THE "METALLURGICAL ENGINEER"

OCTOBER, 1956 Vol. LIV. No. 324

Plant Scale Research

IN the pages of this issue, accounts will be found of the work in progress in the laboratories of a number of research associations in the metallurgical field. The term "laboratories" is used in its widest sense, for, as a glance through these surveys will show, much of the work is carried out on large scale plant. This is true of all research associations, and must necessarily be so, since their purpose is the technical improvement of the industries concerned, whether in terms of quality of product or efficiency in operation. Whilst a certain amount of fundamental work is necessary to establish basic principles, the value of an association's work for industry cannot be finally assessed until large scale trials have taken place. This transition from laboratory experiment to full scale operation is, perhaps, the most important aspect of the work of a research association, or, indeed, of any research organisation concerned with the development of metallurgical processes.

In many cases, of course, the research itself must be carried out on full size plant, and this introduces its own special problems. In a foreword to "Advances in Steel Technology in 1955,"* M. H. Malcor, Chairman of the Institut de Recherche de la Sidérurgie (IRSID), suggests that one of the most obvious reasons why steel technology advances slowly is the fact that the development of new techniques is very costly for an industry which uses plant of extremely large capacity. Experiments on too small a scale generally cannot be extrapolated: in particular, radiation losses and the influence of furnace walls are of quite a different order of magnitude in small and in large installations. A one-tenth scale model, in which water takes the place of liquid pig iron, has been used to study the movements of the bath inside a converter during blowing, and for quantitative examination of the phenomena which occur on the industrial scale. In a similar manner, Perspex models have been used to study the flow of gases in open hearth furnaces—work which has led to improvements in design. On the whole, however, cases where rules of similarity can be applied are comparatively rare, and a substantial part of steel research must, therefore be carried out in the plant, or on a scale which is not too different. This is the reason for the installation at IJmuiden of a one-third scale furnace for the work on the properties of flames used in industry, which is being carried out under the aegis of the International Committee on Flame Research. Similarly, the coking research station at Marienau is equipped with four normal sized chambers, with widths varying from 230 to 480 mm. Other examples which come to mind are the low shaft furnace at Ougrée, which is at the same time an experimental blast furnace, and the one-eighth scale experimental blast furnace set up at the works of the Shelton Iron Company. Tests carried out on such installations are expensive, and it is impossible to conduct many of them at the same time.

The capital involved in the present expansion of the steel industry is enormous, and there is an understandable tendency for managements to use the available financial resources for the construction of plant of a type which has proved itself to be capable of working at a profit, rather than to run the risks inherent in developing a new process. It is, in fact, surprising that so many should have the courage to take big risks in order to launch new methods. Moreover, since conventional steelmaking processes have been gradually perfected over many years, they have arrived empirically at such a state of perfection that any small isolated changes are quite likely to prove harmful. To achieve any improvement, radical changes are needed, and these are, naturally, uncertain of success. Exceptions to this may be found where the development of a process is limited by inadequate materials, the improvement achieved when using chrome-magnesite bricks in place of silica bricks in open-hearth furnace roofs being a notable example.

A new process which is technically possible is obviously of no practical interest unless the cost is at the most equal to that of conventional methods. In this connection, M. Malcor stresses the importance of maintenance costs, the evaluation of which requires long experience. The layman generally underestimates this cost, and many inventors who honestly believe they have discovered very economical processes have come to that conclusion as a result of ignorance in this matter.

The fact that the richest, and often the purest, source of iron is scrap, a product which in many areas is relatively abundant and inexpensive to collect, precludes competition from any reducing process which is not extremely cheap. The direct reduction of ore with natural methane in Italy seemed to the uninitiated to be certain of success from the start. For the process to be economic, however, it is not enough to have ores at normal prices and cheap natural gas, or to obtain reduced iron: spongy iron containing only 10% gangue is an expensive material to treat. Again, the Krupp-Renn process, which is much further developed, is still a costly one, having regard to the use value of the product.

The question of refractory maintenance costs was raised by Dr. J. H. Chesters in connection with the brief reference, in Sir Charles Goodeve's British Association paper on "Steelmaking Since Bessemer," to the Cyclosteel process, which is in the very early development stage at B.I.S.R.A. In this process, ore is converted directly to low carbon steel by injecting finely divided preheated ore into a very hot reducing gas, and although there are formidable obstacles to its establishment as a practical production method, it undoubtedly is extremely attractive. On the other hand, as Dr. Chesters remarked, "Although the blast furnace may be 'fussy' and need special care and maintenance, it does produce metal at about a penny a pound, which demands a very high standard of efficiency from any rival process."

* Prepared by the Secretariat of the Economic Commission for Europe and published in two volumes. Obtainable from Sales Agents for United Nations Publications.

Meeting Diary

2nd October

Institute of Metals, Oxford Local Section. "Molybdenum," by D. O. Pickman. Cadena Cafe, Cornmarket Street, Oxford. 7 p.m.

3rd October

Institute of British Foundrymen, Southampton Section. "Investment Casting Process," by D. F. B. Tedds. Technical College, St. Mary Street, Southampton. 7.30 p.m.

4th October

Institute of British Foundrymen, Stoke Section. "Synthetic Sands," by W. B. Parkes. Stipendiary Court Room, Hanley. 7.30 p.m.

Institute of Metals, London Local Section. "The Bonding of Metals and Alloys to Glass and Ceramics." 4, Grosvenor Gardens, London, S.W.1. 6.30 p.m.

Institute of Metal Finishing. Joint Meeting of North-West Branch and Organic Finishing Group, including visit to the works of John Summers and Sons, Ltd., Shotton, in the afternoon. Evening Meeting: "The Evaluation of a Variety of Organic Finishes on Electro-Zinc Coatings," by P. Costelloe and E. Pace. The Engineers' Club, Albert Square, Manchester. 7.45 p.m.

Institution of Production Engineers, Southern Region. "The Production Engineer of the Future," by E. C. Gordon England. The Great Western Hotel, Reading. 7.30 p.m.

Leeds Metallurgical Society. "Testing," by A. Lenton. Large Chemistry Lecture Theatre, The University, Leeds, 2. 7.15 p.m.

6th October

Institute of British Foundrymen, Bristol and West of England Branch. Joint Meeting with Kindred Societies. "Some Interesting Foundry Techniques," by H. Balme. Glanville Street Public Secondary School, Plymouth. 3 p.m.

Institute of British Foundrymen, Lancashire Branch. Presidential Address, followed by "The Planning and Operation of a Mechanised Core Shop," by J. Hill. Midland Hotel, Manchester. 3 p.m.

8th October

Institute of Metals, Scottish Local Section. "Metallurgical Problems in the Heavy Organic Chemical Laboratory," by Dr. W. L. Wood. Institution of Engineers and Shipbuilders in Scotland, 39, Elmbank Crescent, Glasgow, C.2. 6.30 p.m.

9th October

Institute of British Foundrymen, Slough Section. "The Continuous Casting of Bronze," by Dr. E. C. Ellwood. Lecture Theatre, High Duty Alloys, Ltd., Slough. 7.30 p.m.

Institute of Metals, South Wales Local Section. Chairman's Address: "The Inventions of Bessemer in Relation to Non-Ferrous Metals." Professor H. O'Neill. Department of Metallurgy, University College, Singleton Park, Swansea. 6.45 p.m.

10th October

Institution of Production Engineers, Edinburgh Section. "Welding and Marine Engineering," by J. A. Dorratt. Joint Meeting with the Institute of Welding, East of Scotland Branch. North British Hotel, Princes Street, Edinburgh. 7.30 p.m.

Manchester Metallurgical Society. Presidential Address. G. A. Cuttell. Manchester Room of the Central Library, Manchester. 6.30 p.m.

11th October

Institution of Production Engineers, Leicester Section. "Ultrasonic Machining of Hard Materials," by C. F. Brokles-bury. The Windsor Room, Bell Hotel, Leicester. 7 p.m.

Liverpool Metallurgical Society. Presidential Address. W. Rose. The Liverpool Engineering Society, 9, The Temple, Dale Street, Liverpool. 7 p.m.

12th–14th October

Incorporated Plant Engineers. Southern Regional Conference. Theme: "Future Developments in Plant Engineering." Grand Hotel, Bournemouth.

12th October

Institute of British Foundrymen, Tees-Side Branch. "Foremanship," by F. Shepherd, J.P. Teesdale Hall, Head, Wrightson & Co., Ltd., Thornaby-on-Tees. 7 p.m.

15th October

Institution of Production Engineers, Coventry Section. "Component Production from Metal Powder," by G. R. Bell. The Craven Arms, High Street, Coventry. 7 p.m.

Institution of Production Engineers, Derby Section. "New Techniques in Non-Destructive Testing," by W. G. Cooke. The Derby and District College of Art, Green Lane, Derby. 7 p.m.

16th October

Institution of Production Engineers, Cornwall Section. "Organo-Tin Compounds and Their Application in Industry," by Dr. H. S. Hedges. Joint Meeting with the Institution of Mechanical Engineers and the Cornish Institute of Engineers. The Cornwall Technical College, Trevenson, Pool, Redruth. 7.15 p.m.

17th October

Society of Instrument Technology, South Wales Section. "Recent Advances in American Industrial Instrumentation," by S. S. Carlisle. Physics Lecture Theatre, Cardiff College of Technology. 6.45 p.m.

18th October

Society of Instrument Technology. "The Importance of Minimising Hysteresis in a Process Temperature Controller," by D. M. Boyd. Junior Institution of Engineers, Pepys House, 14, Rochester Row, Westminster, London, S.W.1. 6.30 p.m. for 7 p.m

19th October

Institution of Production Engineers, Eastern Region. "Jobbing Foundry Work Today," by A. Talbot. Joint Meeting with Colchester Engineering Society. Britannia Works Canteen, Davey, Paxman & Co., Ltd., Colchester. 7.30 p.m.

West of Scotland Iron and Steel Institute. Conference on Application of Low Alloy Steels for Welded Pressure Vessels. 39, Elmbank Crescent, Glasgow. 10 a.m.

22nd October

Institute of British Foundrymen, Sheffield Branch. "Bessemer and His Work," by J. Mitchell, C.B.E. Joint Meeting by invitation of the Sheffield Society of Engineers and Metallurgists. University Buildings, St. George's Square, Sheffield. 7.30 p.m.

23rd October

Institution of Production Engineers, Oxford Section. "Aluminium as a Packaging Material," by J. A. Ambler. The North Oxon Technical College, Bath Road, Banbury. 7.30 p.m.

24th October

Institute of British Foundrymen, Birmingham Branch. "Experience in the Use of a Coreless Normal Frequency Melting Furnace," by T. R. Twigger. James Watt Memorial Institute, Great Charles Street, Birmingham, 3. 7.15 p.m.

Manchester Metallurgical Society. "Stress Corrosion," by Dr. T. P. Hoar, Manchester Room of the Central Library, Manchester. 6.30 p.m.

Society of Instrument Technology, Chester Section. "pH and its Measurement," by J. C. Farquhar. Board Room of the Chester and District Hospital Committee, 5, Kings Buildings, King Street, Chester. 7 p.m.

25th October

Institute of Metals, Birmingham Local Section. "Dry Corrosion," by E. C. Williams. Birmingham Exchange and Engineering Centre, Stephenson Place, Birmingham. 6.30 p.m.

North East Metallurgical Society. "Sixty Years of Non-Destructive Testing," by J. F. Hinsley. Cleveland Scientific and Technical Institution, Middlesbrough. 7.15 p.m.

26th October

Society of Instrument Technology, Scottish Section. "A Flexible Electronic Recorder Controller," by S. A. Bergen. Building Centre, 425, Sauchiehall Street, Glasgow. 7.15 p.m.

27th October

Institute of British Foundrymen, Bristol and West of England Branch. "Some Developments in Foundry Sands Practice," by A. Tipper. Grand Hotel, Broad Street, Bristol, 1. 3 p.m.

30th October

Society of Instrument Technology. "Control Engineering and the Automatic Process Plant," by D. S. Townend. Manson House, Portland Place, London, W.1. 6.30 p.m. for 7 p.m.

CO-OPERATIVE RESEARCH

Survey of the Activities of the Research Associations

B.C.R.A. B.C.I.R.A. B.I.S.R.A.
B.N.F.M.R.A. B.S.C.R.A.

The British Ceramic Research Association

By A. E. Dodd
Information Officer of the Association

AN important part of the research programme of the Refractories Division of the British Ceramic Research Association is devoted to the needs of the steel industry ; this reflects the well-known fact that something like one half of the refractories produced in this country are used in blast furnaces and steel furnaces. Though accounting for but a small proportion of the actual tonnage of refractories used in the industry, ladle lining bricks are vital to the steelmaking process, and a new study of these bricks is at present being made.

Earlier Work on Ladle Linings

The first investigation made by the research staff on ladle refractories was concerned with an assessment of the relative importance of the various operating factors on the life of ladle linings. This study was made at three steelworks, and the results were summarized in Iron and Steel Institute Special Report No. 32. It was concluded that the wear of a ladle lining is chiefly a result of chemical attack and solution by the molten slag, and that the volume of slag carried in the ladle is the most important single factor in determining the life of the lining. Abrasion and erosion in the area where the metal from the launder strikes the wall of the ladle was also found to have a serious effect on the brickwork. Within the limits of the observations made, the variations in the tapping and teeming temperatures from one cast to another did not seem to result in corresponding variations in the wear of the refractory. Variations in the basicity of the slag, on the other hand, appeared to be of importance ; this is not surprising, as laboratory tests showed that one product of reaction between such slags and firebricks is anorthite, $CaO.Al_2O_3.2SiO_2$.

The investigation, carried out in 1938–39, did not proceed further owing to a re-arrangement of the research programme to meet the more immediate war-time need (an adequate supply of basic refractories) of the steel industry. Research on ladle linings was resumed some time ago, however, and, with the previously-won knowledge that ladle wear is caused primarily by solution of the brickwork in the slag, and that the composition of the bricks (within the normal range of fireclay refractories) does not seem to have the influence that might be expected, the present programme has as its object an improvement in the physical properties of ladle bricks ; in particular, efforts are being made to produce bricks of low porosity, preferably with a tendency to " bloat " during use, so that the joints shall become closed and the surface of the brick itself shall become still more dense.

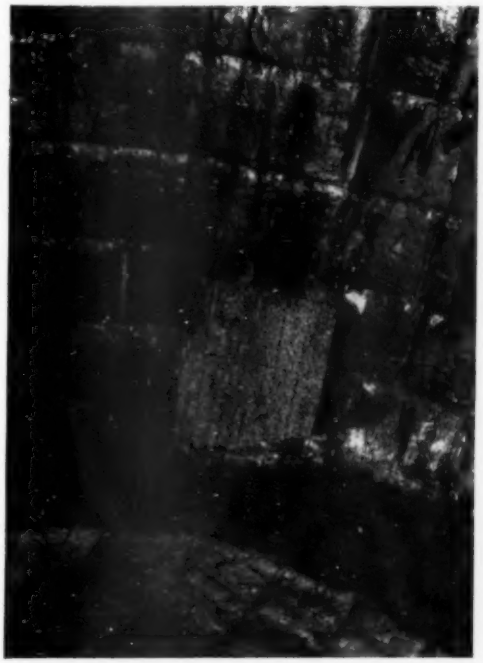


Fig. 1.—Test panel of " bloating " type ladle bricks showing the differences in surface texture and mode of wear.

The Texture of Ladle Bricks

The texture of a firebrick can be altered to some degree by a change in some or all of the clay used, by alteration of the proportion and nature of the grog, and by modifi-

Fig. 2.—Two adjacent "bloating" type bricks removed from ladle, showing porous working face and little evidence of joint wear or slag penetration.

cation of the moulding pressure and firing temperature. The porosity will generally be lower if the clay itself contains a significant amount of alkalis; for example, two fireclays, the one containing 1% alkalis and the other containing 4% alkalis, had porosities of 13% and 7%, respectively, when fired at 1,200° C.; after they had been fired at 1,300° C., the respective porosities were 11% and 6%. Normally, a firebrick containing 4% alkalis would not be used if the operating temperature were likely to exceed, say, 1,300° C., but the intermittent nature of the steel casting process gives a greater margin of safety, owing to the comparatively low thermal diffusivity of a fireclay refractory; it is therefore possible to choose, for ladle refractories, a fireclay containing a relatively high amount of alkali fluxes.

In some experiments on the effect of moulding pressure, an increase in pressure from 2,000 lb./sq. in. to 10,000 lb./sq. in. almost halved the porosity of the fired bricks: however, it was found that the moisture content must be adjusted to suit the particular clay, grog and making-pressure that have been selected. Experimental bricks having a porosity below 10% were readily made by paying attention to these various details.

The "Bloating" of Ladle Bricks

As already mentioned, there is reason to believe that it is an advantage for ladle bricks to "bloat" when heated at, say, 1,300–1,400° C. This "bloating" is evidently caused by the evolution of gas in the temperature range in which the brick has become viscous. It would therefore be expected that, to "bloat," a clay must contain a relatively high proportion of fluxes and some sulphide, sulphate, fluoride or other compound likely to evolve a gas at high temperature. A well-known "bloating" fireclay has been analysed and found to contain about 3½% alkalis and the equivalent of 1·8% SO_3. "Bloating" has been induced in normal fireclays by the addition of alkali and ferrous sulphide, but the effect was much less marked than when these impurities occur naturally in the clay; perhaps the intimacy of mixing achieved during natural sedimentation cannot readily be reproduced under laboratory or plant conditions.

Service Trials

The laboratory experiments that have been briefly described have led to the formulation of a programme of trials at various steelworks. Much work has been completed on the behaviour in service of ladle bricks made of clays selected to give a low porosity.

About a dozen types of brick have been tested. Their composition has varied in the following range: SiO_2, 50–70%; Al_2O_3, 24–43%; alkalis, 0·6–3·2%. The true porosity of these different types of ladle bricks varied from 13% to 30%, and their behaviour in the reheat test (2 hr. at 1,410° C.) varied from a permanent contraction of about 1% to a permanent linear expansion of 40%. The results of steelworks trials suggested that those ladle bricks giving the most satisfactory service have a low porosity (maximum 15%) and a tendency to "bloat" during use, or during testing at 1,410° C. in the laboratory; it would seem to be essential that no shrinkage should occur at any temperature during use. The chemical composition of a ladle brick and its refractoriness do not seem to be of importance. These findings have formed the basis of recommendations to ladle-brick manufacturers.

Fig. 3.—Two adjacent ladle bricks of the normal type removed from ladle, showing marked joint wear and metal and slag penetration at the joints.

The British Cast Iron Research Association

By Dr. J. G. Pearce, O.B.E.
Director of the Association

Bordesley Hall, Alvechurch, Birmingham, headquarters of the B.C.I.R.A.

A STRIKING feature of the year has been the success of the Association's short courses and conferences. Several years ago the number of applications from industry for information on sand testing and control became so great that short study courses were inaugurated at B.C.I.R.A. headquarters, such courses being attended by a group of 12 members of staff of different member-firms. This group is small enough to permit personal contact with the B.C.I.R.A. staff during the talks on the subject, and to enable each student to carry out tests for himself on the equipment available. By the end of the current calendar year 40 such courses will have been held, each of four days' duration, with a total attendance from the industry of 470. In these courses and the Association's conferences, 16 of which have been held since 1948, a way has emerged of providing the necessary personal contact between the staff of the Association and those in industry, and thus supplementing the information and advice provided by visits to member-firms on specific matters and the formal reports which are issued in the Association's Journal. A conference in March, 1956, on the CO_2 process proved to be so popular that it had to be repeated in May, with a total attendance of over 480. The papers given and the discussions which followed constitute the whole of the August issue of the Association's Journal. A further publication which must be mentioned is the book "Foundry Ventilation and Dust Control," following the Harrogate Conference on this subject in April, 1955. This work provides the most comprehensive collection of data on foundry dust control available at the present time in any language, and is of special importance, not only in relation to the Iron and Steel Foundries Regulations, now in force, but also the Clean Air Act of 1956.

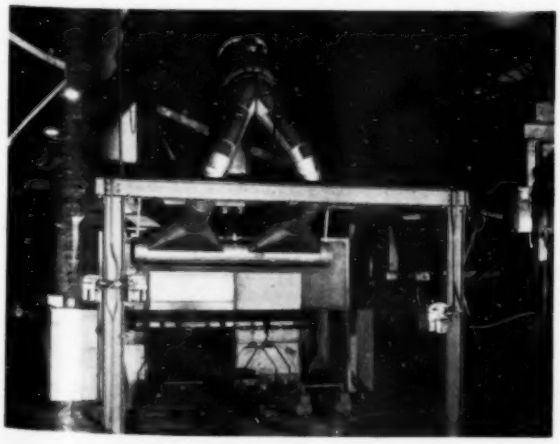


Fig. 1. Foundry knockout operating satisfactorily on principles evolved by the B.C.I.R.A.

Development Department

This department continues its advisory service to member-firms on raw materials, metallurgical and foundry problems, melting practice and finishing processes, and deals with about six enquiries per working day, many of which entail visits to the establishments concerned.

The foundry Atmospheres Section, which forms part of this Department, also provides an advisory service on problems arising from the Iron and Steel Foundries Regulations, and some 125 additional enquiries were dealt with under this head, involving 74 foundry visits, together with other visits needing more prolonged attention on special problems relating to the foundry knock-out and general ventilation problems. The first knock-out to be designed on the basis of the principles worked out from the Association's experimental work, and described in the above-mentioned book on dust control, is now in very satisfactory commercial operation, and an illustrative view is shown in Fig. 1. The work done by the Association on pedestal and swing-free grinders is now well known. Existing pedestal grinders can be fitted with a commercially available external dust control unit, and several makers now embody the system as an integral part of new

machines. The ordinary wire-brush is still largely used in some establishments for cleaning castings, and the method recommended of providing this with an air exhaust supply for dust removal in this normally dusty operation is shown in Fig. 2.

The Scottish Laboratory at Blantyre also functions as an outlier of the Development Department, and deals with the problems of foundries of Scottish member-firms.

Operational Team

The Operational Team has continued its work and, since its inception in June, 1950, has paid over 650 visits to foundries with the object of advising how productivity can be increased. The Team is working towards the establishment of criteria which will provide absolute, as distinct from relative, standards of performance, and such criteria are already available for metal melting in relation to the number of men employed, the method of charging, and the molten metal output.

Research Department

Phosphorus in Foundry Iron

A Panel has been set up to review the possibilities of deriving from native British phosphoric iron ores, a relatively low phosphorus foundry pig iron for the ironfounding industry. A start has been made on the application of top-blowing by oyxgen, and the possibility of eliminating phosphorus and yet retaining an appreciable amount of carbon in the melt. In this connection, it is intended to equip during the coming year the building already erected as an experimental melting station, and some of the equipment will be required for this programme.

Mechanical Properties

A special Panel has been formed to supervise work on engineering cast irons, to see whether any relaxation of present restrictions on the use of cast irons at temperatures above 400°–450° F. can be justified. Growth tests on 30 different materials are now in progress, and when the most suitable materials have been sorted out by long-term growth tests, creep tests will follow, the necessary equipment for which has been ordered.

The influence of understressing on fatigue properties has been studied and, contrary to the indications given in the literature, little effect has been detected on pearlitic, flake and nodular cast irons.

A considerable amount of work has been done on the mechanical properties of the nodular cast irons, both in pearlitic and ferritic forms; in particular, the effect of variations in heat treatment on the ferrite grain size of pearlitic nodular cast irons is being considered, and the appropriate treatment for the production of a fine grain size has been worked out. By refining the grain size, it is possible simultaneously to raise the ultimate stress and proof stress and to lower the impact transition temperature, a factor of considerable importance in meeting the conditions which provoke brittle fracture. Other work concerns the temper embrittlement of ferritic nodular irons and the influence of trace elements on the mechanical properties of such materials.

Corrosion

Work continues, in conjunction with the British Shipbuilding Research Association, on the prevention of pitting attack on cast iron propellers by means of cathodic protection. A number of vessels have been fitted with magnesium anodes and their progress in service is under observation. A design of shrouded anode has been developed by the Association to fit to the propeller tail-shaft to minimize this attack. A study of the cathodic protection of underground cast iron mains continues, and a considerable number of enquiries from manufacturers and users of iron castings on general corrosion problems has been dealt with.

Fig. 2.—Wire brush for cleaning castings, fitted with exhaust air supply to remove dust.

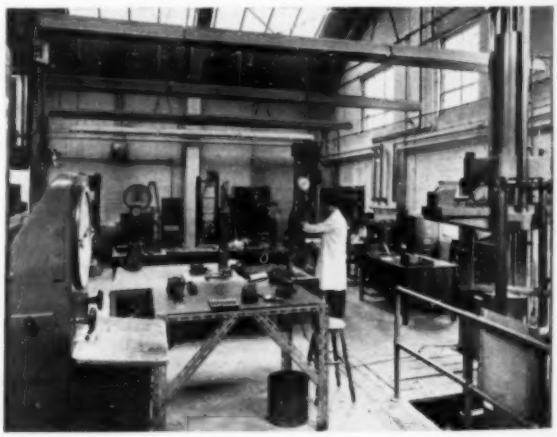


Fig. 3.—General view of the mechanical testing laboratory.

During the year, work has begun on the possible influence of anti-freeze solutions on the corrosion of the waterways of diesel engines. The decomposition of ethylene glycol is being studied, together with the depletion of corrosion inhibitors under conditions similar to those in the cooling passages of an engine.

Methods of Analysis

The methods of chemical analysis used in the industry and by the Association are continually under review, and considerable co-operative work is carried out with works laboratories in the industry to evolve the best and quickest methods, and to make good deficiencies. In particular, speedier methods of slag analysis have been investigated, and interest is being shown in methods of

analysis for small amounts of residual elements such as lead, antimony, boron and arsenic. Work continues on the spectrographic analysis of slags.

Fuels and Furnaces

The building now completed as an experimental melting unit is at present being equipped, and will contain not only a vacuum furnace and a half-ton high frequency furnace, but a twin cupola installation to work with hot or cold blast, with detachable well and melting zone sections. Provision is also being made for water-cooling the shell and for various types of lining —acid, neutral and basic.

Fig. 4.—General view of the chemical laboratory.

Moulding and Core Sands

The apparatus designed and used by the Association for testing sands at elevated temperatures by dielectric heating has aroused considerable interest both at home and abroad, and the possibility of building apparatus to permit a still faster rate of heating is being considered. The interest in the CO_2 process mentioned above has resulted in the establishment of a technique for the preparation of test-pieces and their subsequent gassing treatment. Using this technique, the influence of moisture content, silicate ratio, clay content and gas evolution have been studied. The possibility of re-using sand from the process, usually regarded as unusable in normal clay-bonded sand, is also being examined.

Gases

Work carried out during the past year has been largely concerned with the influence of hydrogen, determined by vacuum heating. A process evolved by the Association before the war for the production of undercooled graphite structures by the use of titanium additions, followed by gassing with carbon dioxide, is now capable of a somewhat fuller explanation. The influence of carbon dioxide has now been shown to be due to the elimination of hydrogen. Some interesting results have come out of work on the influence of gases in the production of pinholes in ordinary and nodular cast irons.

White and Malleable Cast Irons

Previous work has shown that the structure of white iron can take two quite distinct forms, and that these

Fig. 5.—Shell moulding train.

two forms have differing mechanical properties. The reason for the difference is being elucidated. Comprehensive tests have now been made on the best method of casting sound malleable test bars to facilitate a revision of the appropriate B.S.I. Specification. Studies of decarburisation rate and sulphur pick-up during annealing are also being made.

Ingot Moulds

For many years the Association has been interested in cast iron ingot moulds, and has carried out work in conjunction with the British Iron and Steel Research Association. Some possibilities of improvement as a result of experimental work are now opening up, and these are being pursued.

Soundness of Iron Castings

Considerable attention is being given to this important problem, and a detailed survey of drawing in light castings has been made in the foundry of a co-operating member. The anomalous sinking on the underneath face of light castings where there is a boss in the top section is also being examined. Unsoundness in nodular cast irons is also being studied.

Heavy Plate Mill Order

A NEW four-high plate finishing mill is now being built for the Appleby-Frodingham Steel Company by Davy and United Engineering Co., Ltd., at a cost of over half-a-million pounds. This mill is being designed to roll plate up to 12 ft. wide, up to 4½ in. thick, and with a maximum length of 65 ft. Fed by an existing roughing mill, it will initially be capable of producing about 9,000 tons of plate in a week of three-shift working.

The principal purpose behind the installation of a four-high mill for plate rolling is to obtain improved quality in the finished plate, as well as to increase output. Modern plate rolling demands designs of great strength and power. Thus the roll housings for this new mill will weigh about 140 tons each when finally machined; the two back-up rolls, both 150 in. long on the barrel, are themselves likely to weigh about 72 tons each; to drive the mill two 4,000 h.p. motors will be needed. The new mill will be completed and ready for operation in June, 1958.

The British Iron and Steel Research Association

THIS year BISRA celebrates its tenth anniversary. To illustrate its current research, the following items have been chosen from the work now being carried out by the Association's five divisions, Ironmaking, Steelmaking, Mechanical Working, Metallurgy (General), and Plant Engineering, and its three departments, Physics, Chemistry and Operational Research.

Ironmaking

The need to provide the blast furnace with suitable materials lies behind much of the research done by BISRA's Ironmaking Division. Two aspects of this work are illustrated by studies of the permeability of typical blast-furnace burdens and research on the sintering process.

Permeability of Blast Furnace Burdens

A test apparatus (a voidometer) as shown in Fig. 1 has been used to measure the permeability of typical burdens charged to blast furnaces. It consists of a vertical cylinder 3 ft. in diameter and 6 ft. high with equipment for measuring pressures at various points up the stack. The voidometer has been used for a series of tests with coke of various sizes. Some unexpected results have been obtained. Thus, coke of two different sizes charged fully mixed can have a higher permeability than when charged in a number of separate layers. It was also found that adding small amounts of certain undersize coke to a sample of screened coke increased its permeability. A series of tests is in progress on the effect of layering and mixing ores and mixtures of ore and coke. Special attention is being given to the conditions at the interface of two layers differing in size. Although the conditions in the voidometer are not necessarily exactly the same as in the blast furnace, it is probable that some of the more important phenomena are common to both.

Fig. 1.—Equipment (voidometer) for determining the permeability of burden materials.

Sintering

Work on the sintering process has been carried out in a laboratory-scale sintering pan. It has been shown that the fundamental factors controlling the process are the same for all materials. Chemically inert materials with widely varying water content, and also carbonates and iron ores have been used for this work.

It has been shown that when the bulk density of the bed is low, the flame front travels through it faster and the temperature at any part of the bed rises and falls faster than when the bulk density is high, other conditions being the same. As the speed of the flame front varies inversely with the bulk density, the quantity of air needed to sinter a given weight of material is always of the same order. Also, if exothermic and endothermic reactions are allowed for, the quantity of heat needed to produce a given temperature distribution through the bed is very similar. If, however, the amount of heat required for the endothermic reactions is excessive, as, for example, if the bed is composed entirely of marble, the normal temperature distribution cannot be obtained, however much fuel is added, because the chemical reactions cannot take place in advance of the flame front. A normal temperature distribution can be obtained, however, with as much as 66% of marble in the raw mix.

The effects of changing the nature of the fuel and the amount of oxygen in the sintering atmosphere have also been studied. As would be expected, a high oxygen content, particularly when the fuel is highly reactive, gives a marked increase in the rate at which the flame front travels, but, unexpectedly, it lowers the peak temperature and broadens the high-temperature zone. The explanation has been given by experiments in which a hot inert layer was placed on top of a bed of similar material, without fuel or water, and air was sucked through the bed in the usual way. As heat was extracted from the top of the bed and given up to the material below, a hot zone passed down the bed. The speed at which this zone travelled and the quantity of air needed to pass it right through the bed were established. They were found to be almost identical with the speed of the flame front and the quantity of air needed to sinter the bed with coke. Hence, in a sinter bed, the hot zone caused by transfer of heat from the upper layers and the zone of burning fuel start together and travel through the bed at the same rate; this accounts for the high temperatures that are reached. With a highly reactive fuel and an atmosphere rich in oxygen, the fuel burns faster, the flame front travels ahead, and the two zones no longer coincide. This creates a broader combined hot zone at a lower temperature.

Knowledge of the chemistry of the removal of sulphur during sintering has now been applied to practical sintering conditions. When Ouenza ore with additions of

Fig. 2.—Oxygen lancing in arc furnace at Brymbo Steel Works, Ltd.

pyrites or gypsum was sintered in the laboratory sinter pan, less sulphur was removed from the top than from the bottom of the bed, using the optimum amount of coke for sintering. In general, the greatest amount was removed with less coke than is needed to produce a sinter of adequate strength. Any method of making sinter with less carbon in the lower part of the bed and increasing the temperature of the top of the bed, for example by preheating, should increase the removal of sulphur during sintering.

Steelmaking

Phosphorus Reduction

Until recently, pre-refining of high phosphorus irons by top-blowing with oxygen has been restricted to desiliconizing, but good progress has now been made in extending the method to phosphorus reduction in medium- and high-phosphorus irons. At the Brymbo Steel Works (Fig. 2) it has become routine practice to refine, with the oxygen lance, iron containing about 0·8% phosphorus and 0·8% silicon to iron with less than 0·1% phosphorus and only a trace of silicon, without reducing the carbon content below 2·0%. The valuable experience gained at this works has been made available to BISRA for production-scale experiments at another works, where the aim is to refine irons containing from 1½ to 2% phosphorus ; these experiments have already shown that this can be done, and the possibility of continuing the treatment to produce steel is being examined.

Continuous Casting

The new continuous casting plant built at the Sheffield Laboratories last September has worked very satisfactorily. The ingots cast, as in Fig. 3, have been mostly 4 in. square sections of a large variety of plain carbon and alloy steels. Many of the casts have been made to the specifications of member firms that are investigating the suitability of continuously cast ingots for their markets. So far, tests have shown that hot rolling completely welds up the axial unsoundness of continuously cast plain carbon steel. Rolled bar of continuously cast steel was upset forged from 1¼ in. round to 4 in. round and passed the normal production inspection without any defect caused by original material defects being found. At present the highest satisfactory production rate on this machine is a little more than 7 tons an hour, but preliminary investigations into the effect of secondary cooling indicate that rates considerably higher than this will be possible.

Mould Dressings

For any given steel there is a range of teeming speeds and temperatures in which ingot defects occur most frequently. These ranges are often very small, but mould dressings provide a means of extending them, so that although both speed and temperature may vary while a heat of steel is being poured, the quality of the ingots is maintained.

The effectiveness of mould dressings with different properties has been studied by using an experimental technique in which metal is poured into a special mould with a transparent panel, so that cine-films can be taken of the movement of the metal against the mould wall during teeming.

In the tests, molten steel was poured into small moulds treated with various mould dressings. The surfaces of the cast blocks were afterwards examined. The work has made it possible to make recommendations on mould dressings. Of those generally available, the volatile ones offer the most advantages. They are the most effective because (*i*) they prevent the surface of the steel from oxidizing ; (*ii*) they keep surface films and slag away from the interface between the steel and the mould ; (*iii*) they prevent the surface of the ingot from becoming

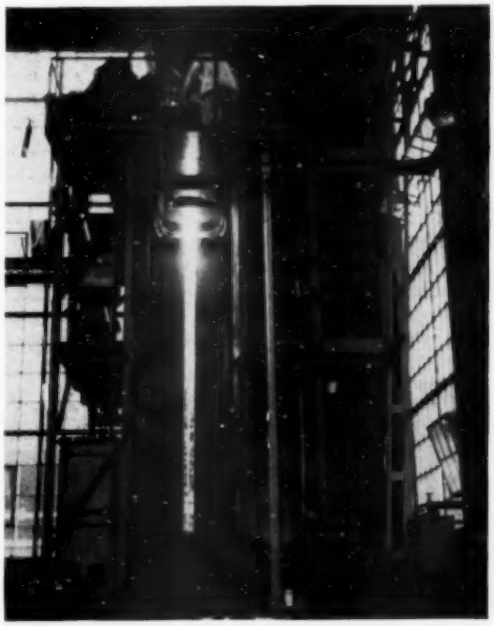


Fig. 3.—Continuous casting at BISRA's Sheffield laboratory.

Fig. 4.—Section of ingot head cast in feeder head lined with exothermic tiles.

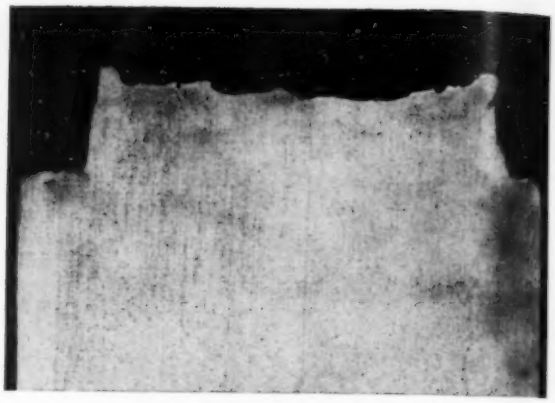


Fig. 5.—Section of ingot head cast in feeder head lined with insulating bricks faced with exothermic material.

excessively decarburized; (*iv*) they prevent splashed steel from sticking to the wall of the mould; and (*v*) they allow the metal to rise smoothly up the walls of the mould.

Ingot Feeder Heads

Efforts to increase the yield of good material from killed ingots by devising more efficient feeder heads have met with encouraging results during the last few years. In general, these efforts have been concerned with conventional designs, but recently attention has been given to the use of exothermic materials that can easily be moulded into the feeder head lining. These materials consist essentially of aluminium powder and a refractory filler; when used in feeder head linings, they react exothermically and become equivalent to a highly preheated porous refractory tile. The "heat content" can thus be regarded as already provided, and the tile abstracts little or no heat from the steel in the head until after the body of the ingot has solidified. Heads fully lined with these materials give almost perfect efficiency of feeding, as Fig 4 shows, but their cost is such that they may not be economical except for casting alloy steels. Nevertheless, in co-operation with the makers of these exothermic materials, BISRA is developing a technique which appreciably extends the applications of these linings. This new technique uses the exothermic material as a hot-face lining on a highly insulating material. Fig. 5 shows an ingot cast with a head of this type, containing only a third of the quantity of exothermic material in the head used for the ingot illustrated in Fig. 4. This reduction is achieved, moreover, without loss in feeding efficiency.

Mechanical Working

Successful projects reaching the stage of industrial application include the following:

Rolling

The first industrial installation of the BISRA automatic gauge control system has been made on a reversing cold reduction mill at the Lancashire and Corby Steel Manufacturing Company by the Davy and United Engineering Co., Ltd. (Fig. 6). The results so far obtained indicate that this type of automatic gauge control will keep the coil very closely to the required constant gauge along its whole length. The resulting higher yield of on-gauge product will give a direct saving, and the work of the mill operators will be simplified. The unit has now been working on a three-shift basis for several months. It is understood that further units for production mills for ferrous and non-ferrous materials have been ordered in this country and abroad, and considerable interest is being shown in Canada and the U.S.A.

Wire Drawing

The BISRA nozzle-die unit for dry wire drawing, evolved from research into hydrodynamic lubrication, is now coming into use, and some marked improvements of lubrication and die performance have been reported. In recent trials of the nozzle-die unit with mechanically de-scaled rod, full production speed was maintained and the die performance was as good as with pickled and limed rod. One nozzle-die unit placed in the roughing hole appears to be sufficient to improve lubrication all along the line. Two types of the nozzle-die unit are available: one in which the nozzle and die are made in one piece, and one in which the nozzle is separate and can be used, after a little modification, with conventional dies.

Deep Drawing

The design of the Swift cup-drawing test for deep-drawing steels has been standardized, and a testing procedure has been specified which ensures consistency of performance between different presses in different places. Extensive trials to compare test results with actual performance have been carried out in a large press shop; they suggest that various qualities of deep-drawing steel can be graded according to their behaviour in the cupping press. Contact is being maintained with other countries where similar tests are being developed. Sweden in particular, and a meeting of representatives from various countries interested in the test is planned with a view to standardizing the method of carrying out the test. This is a necessary preliminary to further investigation of the test by industry.

Work is at present in progress at Sheffield University on the scale effect in cup-forming. Results obtained so far indicate that a cup of smaller size may be equally suitable, and that the Swift test could thereby be brought more closely into line with similar tests used abroad.

Recovery of Waste Pickle Liquor

During the past year, trials of the pilot plant at Swansea for recovering sulphuric acid from waste pickle liquor by the autoxidation process have confirmed that the process is efficient and economical. Recent tests have shown that acid of 41% strength can be prepared with an efficiency of conversion of 97½% of the sulphur dioxide to acid. It has also been found that a directly fired furnace can be used without detrimental effects if the input of ozone is increased. The ozone oxidizes any poisons present in the furnace gas, and thus maintains the efficiency of the autoxidation. Plans for a full-scale plant have been prepared. In the meantime, schemes for automatically controlled closed-cycle pickling plants, are being studied.

Fluid Dynamics

Research on air pollution has been expanded to include problems associated with steelmaking processes and equipment that are liable to come within the scope of the proposed legislation on atmospheric pollution. Progress has been made in surveying gas-cleaning equipment. Measurements are being taken of the amount and nature of the emissions likely to be met, and the efficiencies of various cleaners will be determined experimentally before specific recommendations can be made. Suitable apparatus is being constructed for measuring gas volumes, temperatures, and dust contents produced by various steelmaking processes. For this purpose, a filter made from glass-wool fibre has been developed and tested in the laboratory and in steelworks. It can withstand temperatures up to 350° C., and retains fine particles of metal oxide fume. Standard equipment for collecting dust and fume particles and measuring their size is being built.

One of the most difficult air pollution problems facing the steel industry is that of removing iron oxide fume created by a number of steelmaking processes. Although it has been reported that electrostatic precipitators are successful in some cases, the capital costs of installing them are high. If a suitable means of increasing the size of the particles in such fume could be found, it would be both simpler and cheaper to collect them. Preliminary experiments in which the particles have been made to act as condensation nuclei for water vapour have shown promise. A small-scale Venturi scrubber, shown in Fig. 7, has been constructed for using and studying this effect in cleaning air laden with iron oxide fume. Other methods of increasing the particle size, such as agglomeration with other materials, are also being studied.

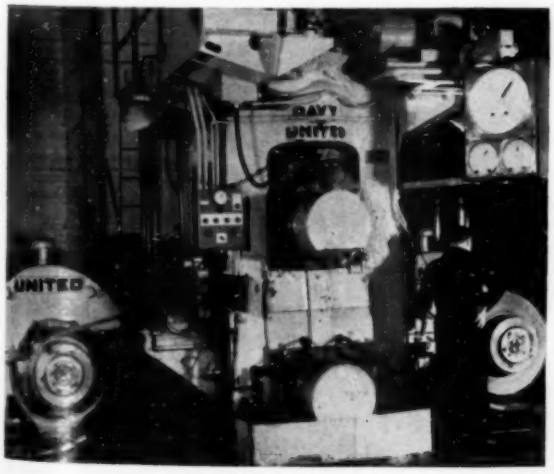


Fig. 6.—BISRA type automatic gauge control installed on a 21 in. cold rolling mill by the Davy and United Engineering Co., Ltd., at the Lancashire and Corby Steel Manufacturing Co., Ltd.

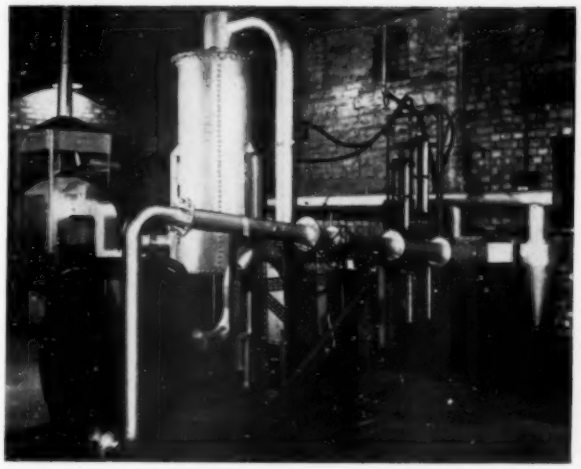


Fig. 7.—Laboratory plant for investigating the removal of iron oxide fume by a Venturi scrubber.

Bimetallic Aggregates

Many tests have been made on the mechanical properties of coarse bimetallic aggregates consisting of inclusions embedded in a matrix. These aggregates have been made up in the laboratory to simulate the fundamental structure of metals consisting of two phases. There are many variables in this kind of problem : the size, total content, distribution, and mechanical nature of the inclusion, and its degree of bonding with the matrix. Ductility, ultimate tensile strength, and yield point are all reduced by the existence of coarse inclusions, whatever their nature. The degree of bonding is more important when the inclusion has a low yield point than when the inclusion has a high yield point and is relatively much stronger than the matrix material. It has also been shown that simple unfilled holes bring about the same kind of changes in properties as inclusions, and the use of physical models is thus permissible, simple and economic. The effects of finer aggregates are also being studied, using bimetallic materials formed by powder metallurgy.

Lamination Detector for Inspecting Steel Sheet

Laminations in steel sheet result if defects such as piping, blowholes, or segregation are present in the ingot from which the sheet is rolled. During rolling, such flaws become flattened and elongated, and the sheet which finally emerges from the mill contains internal discontinuities parallel to its surface. These may be from a fraction of an inch to several inches wide, and from an inch or two to several feet long.

It is important to have some means of detecting the presence of laminations in steel sheet ; in deep drawing

Fig. 8.—The BISRA lamination detector.

or pressing, for example, a laminated sheet may burst in the press and cause considerable damage to dies and tools and disrupt production. Unfortunately, even extensive laminations may not give rise to any visible abnormality at the surface of the sheet. BISRA's Physics Department has developed a lamination detector (Fig. 8) which makes use of the fact that the presence of a discontinuity modifies the path followed by an electric current flowing through a sheet when a potential difference is applied to two points on opposite sides of it.

The BISRA lamination detector has two pairs of contacts which are mounted on duralumin tongs. The points of these contacts are rounded to prevent the sheet being scratched, and to prevent swarf on its surface from bridging the insulated gaps between the points. A millivoltmeter is mounted on the tongs so that changes in potential can be observed while the contacts are moved across the sheet. The instrument will accommodate strip up to 3 ft. wide and up to 0·1 in. thick. It is completely portable ; a 12-volt car battery supplies current at 10 amps.

Laminations $\frac{1}{4}$ in. or more wide can be detected reliably in cold-rolled sheet with this instrument, and even narrower ones can sometimes be detected. Laminations in hot-rolled strip cannot, however, be detected by this method. The present instrument is intended primarily for examining the ends of cold-rolled coils, where lamination is likely to be found. A version suitable for continuously inspecting moving strip is now being developed.

Metallurgy

Studies of Grain Boundaries

Many phenomena have been attributed to the effects of solute elements on the grain boundaries in steel. Several techniques have, in the past, been used in attempts to confirm such hypotheses, but with indifferent success. A new approach using internal friction measurements has shown some promise, and is now being used to study the properties of grain boundaries in ferrous materials. The specimen for studying the variation of damping with temperature is in the form of a wire which suspends a torsion pendulum bob. The damping has a maximum which can be related to the grain boundary properties of the material. In *alpha*-iron, a peak, due to the presence of grain boundaries, occurs at about 500° C., so that it is necessary to carry out the tests *in vacuo*. The tests are being carried out on high-purity iron in the first place, and will be extended later to iron containing other elements, in order to observe any changes in characteristics. Preliminary results indicate a strong dependence of damping on grain size, and that the peak in the curve obtained by plotting damping against temperature does not occur unless the specimen has a grain size which is small compared with the cross-section.

Fatigue

BISRA's Metallurgy Division is investigating the influence of metallurgical factors on the fatigue properties of steels, and has carried out more than 2,000 fatigue tests in the past three years.

One difficulty in measuring the fatigue limit for a material is the wide "scatter" of results in tests. Statistical methods are being used in BISRA's fatigue research in order to provide a more adequate picture than is given by conventional S-N curves.

Five hundred fatigue tests have been completed on a cast of low-alloy steel to B.S. 970, En 100 specification. The steel had been heat-treated in the form of $\frac{7}{8}$ in. diameter rolled bars to an ultimate tensile strength of 60–65 tons/sq. in. This cast of acid open-hearth steel was found to be fairly uniform throughout, although there was a statistically significant improvement in longitudinal fatigue properties towards the top of an ingot ; the steel from this part of the ingot had a slightly higher tensile strength, caused by the segregation of carbon, sulphur, and phosphorus. Non-metallic inclusions appear to have no influence on the fatigue properties.

Five hundred fatigue tests have also been completed on a cast of $1\frac{1}{2}$% nickel-chromium-molybdenum steel (B.S. 970, En 24 specification) heat-treated to 80–85 tons/sq. in. ultimate tensile strength. The results of these tests have not yet been fully analysed. A similar experiment is now in hand with this same cast of steel, heat-treated to 110–120 tons/sq. in. ultimate tensile strength.

Engineering

Translator Control

The maintenance of control gear is simplified by dividing the equipment into easily replaced "packages," each of which performs a single function. This packaging of equipment has prompted fresh thinking about the functions of controls, and has lead to the concept of "translation." This is best illustrated by a specific example. A translator control for a rolling mill would receive data on the initial size of the ingot, the size of the final billet required, the number of the pass, and the scheduled number of passes. All this information is translated by reference to an internal "dictionary" within the translator, which feeds to the mill details of the screw settings, tilt, and roll hole. As many as 150 schedules can be incorporated in the translator's dictionary. Some of the data required for the input to the translator can be obtained from the state of the mill drive, thus providing closed-loop control.

Oil Seals

A survey has been made of various types of seals used for roll-neck and roller table bearings. These seals are

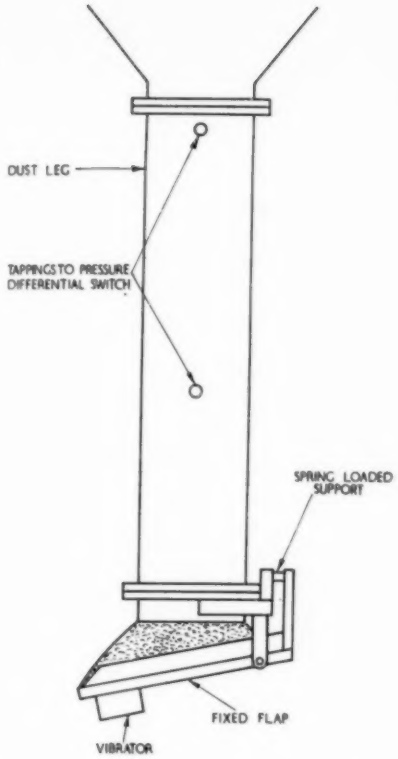


Fig. 9.—Diagrammatic sketch of dust leg designed by BISRA.

necessary to keep out water, mill-scale, and rolling oil, as well as to keep the lubricant in the bearing. They have to withstand arduous conditions, and a single failure can be very expensive.

The Plant Engineering Division of BISRA has recently surveyed the various types of lip seals that are available. This survey has shown that :

(1) The lip seal will give reasonably good service under all but the most arduous conditions, but it demands care in fitting, a smooth land surface, adequate lubrication of the lip, and a minimum of eccentricity. In other words, careful attention to detail is necessary.

(2) A synthetic rubber lip seal should be tailor-made for the job, all details of the operating conditions being submitted to the manufacturer.

(3) Many of the difficulties experienced when using lip seals are caused by imperfectly designed bearing chocks and seal housings which it is impracticable to alter.

(4) Lip seals, even in duplicate, do not provide sufficient protection to the bearing if abrasive scale is likely to be present. Mechanical-type water seals, labyrinths, and slingers deserve wider application, either in combination with lip seals or even, in certain instances, to replace them.

Some adaptations and developments of existing seals that are thought to be worthy of attention are :

(*a*) A lip seal would greatly benefit if the coefficient of friction between the lip and the land could be reduced. A figure quoted by two independent investigators is 0·2–0·3. A lower coefficient of friction would reduce the heating, ageing, and abrasion of the lip, and might allow a higher degree of lip loading to be applied, if required. Oil seal manufacturers are experimenting with molybdenum disulphide for this purpose. Poly-tetrafluoethylene might also be considered.

(*b*) The use of compressed air between a dual rubbing seal arrangement. Pressure via another medium such as oil or grease might also be considered ; this principle is the basis of the ring-type hydrogen seal installed on turbo-alternators.

(*c*) A dual-purpose slinger. Adequate and separate drainage arrangements for the bearing oil and for the water or rolling lubricant would have to be incorporated in the seal housing. Tests on the minimum speed for effective operation are being carried out by BISRA.

Dust Trap for Wind Legs of Sinter Plant

Existing dust collecting hoppers fitted to the wind legs are closed by simple flaps. If, as sometimes happens, a flap remains open longer than is needed to empty the hopper, air is drawn through the opening, causing significant wastage of fan power.

A dust leg seal without seating surfaces, which uses the column of material to provide a seal, has been designed by BISRA. The arrangement of the prototype is shown diagrammatically in Fig. 9. It consists of a standard dust leg with an inclined plate attached to it, forming the bottom support for the material. The angle of inclination of the plate is slightly less than the angle of repose of sinter fines, so that no discharge takes place under static conditions. Fixed to the underside of the inclined plate is an electric vibrator, which is actuated automatically when the dust leg is full, and is kept in operation until the height of the column of material falls down to the lowest level considered sufficient to maintain a reasonable seal.

The apparatus has been satisfactorily tested in the laboratory and offers, as well as a reduction in air leakage, several advantages.

Physical Chemistry

Present knowledge on the oxygen potential of pre-refining and steelmaking slags is by no means adequate. Experiments are therefore being conducted to measure this property by equilibrating slags with mixtures of carbon dioxide and carbon monoxide of known composition at a given temperature. It has been found that for a given temperature and oxygen potential the Fe^{+++}/Fe^{++} ratio in the slag decreases continuously with increase in the silica and phosphorus pentoxide contents of the slags. This is caused by (*a*) reduction in the activity of iron oxide in slags rich in acidic oxides, and (*b*) dissociation of the ferrite anions in the presence of large amounts of Si-O and P-O oxyacid radicals. The results indicate that the ratio of Fe^{+++}/Fe^{++} in the FeO-Fe_2O_3-SiO_2-P_2O_5 system to that in the FeO-Fe_2O_3-SiO_2 system, at the same silica concentration and oxygen potential, decreases continuously with the concentration of phosphorus pentoxide. This relationship appears to be independent of the concentration of silica and the oxygen potential of the slag over a wide range. The work has now been extended to more complex slags.

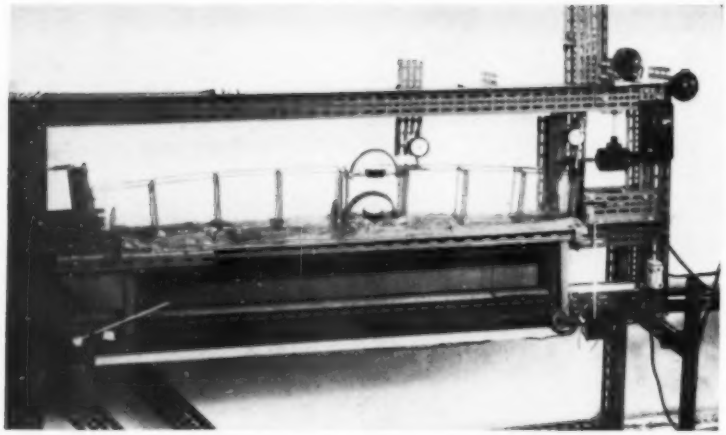


Fig. 10.—Model of open hearth furnace roof used to find the best design of a basic furnace.

Laboratory and works-scale experiments indicate that hot metal containing from 1 to 2% of phosphorus can be de-phosphorized down to 0·3–0·5% phosphorus by top-blown oxygen at temperatures below 1,400° C., in the presence of large amounts of carbon.

Refractories and Slags

An extensive scheme of comparative trials has been carried out on different types of basic brick, using full-scale production open-hearth furnaces in Great Britain and abroad. The results show that the quality of the brick has very little effect on the durability of the roof, when compared with other factors.

It is considered that the design of roof supports is among the more important factors. Although most basic furnace roof supports take some account of the effect of thermal expansion of the bricks on the behaviour of the arch, they do not at present fully allow for it. By means of a model fitted with an expansile brick arch (as shown in Fig. 10) a design has been worked out which will hold a roof arch uniformly at all temperatures and at all thicknesses during wear. A basic brick panel constructed in this way is to be built into the roof of a 200-ton open-hearth furnace.

The porosity of many blast furnace slags, whether air-cooled or water-cooled (foamed granulated slag), and of some lavas (pumice) has been shown to be due to gas bubbles being trapped within the melt. These gases are generated internally by ferric or manganic ions oxidizing the sulphide ions according to the reaction.

$$4Fe^{+++} + 2S^{--} = 4Fe^{++} + S_2 \text{ (elemental)}$$

Ferrous ions, initially present in the magma or slag, are oxidized at surfaces exposed to air or steam when the liquid is emitted. These ions diffuse in as oxygen carriers to the sulphide ions. In a bloating ladle brick the reaction goes further ; the ions are already oxidized and the following reaction takes place :

$$6Fe^{+++} + S^{--} + 2O^{--} = 6Fe^{++} + SO_2$$

One practical application of the mechanism in slag has been successfully tried on a works scale by blowing air into a blast furnace slag ladle to oxidize some of the sulphur and so produce on cooling a dense, i.e., non-porous, artificial mineral.

An idea for a self-lining blast furnace has reached the stage where the engineering details are being worked out for a full-scale furnace. This design was evolved on models, which showed that the burden could be trapped by means of water-cooled shelves to form and maintain its own lining, which has been shown to acquire suitable properties. The potential benefits are: savings in labour and refractories, better engineering, and most important of all, gains in output by avoiding shut-downs for repairs.

Corrosion

A systematic investigation has been made into the effects of small amounts of alloying elements on the corrosion resistance of mild steel. The improvement resulting from suitable additions has been found to be greater for atmospheric exposure than for immersion in sea-water. The most useful alloying elements for atmospheric exposure are chromium, copper, and nickel ; for sea-water immersion the most efficient is chromium. When exposed outdoors at Sheffield, the most resistant steels corroded at less than one-third the rate of unalloyed mild steel, whereas in sea-water the maximum effect of the additions was roughly to halve the corrosion rate.

A final report will soon be issued describing the relative behaviour of mild steel and three different types of low-alloy steel when used as floor plates in railway wagons. The experimental work was started in 1939 and has just been completed. In coal wagons, the floor plates are subjected to corrosive attack and abrasion ; in these circumstances also the low-alloy steel plates proved superior, lasting one-third longer than those of mild steel.

Unpiled wrought iron is laminated in structure, consisting of alternate quickly-corroding and resistant zones. These differ in the accessibility of sulphide to corroding agents. In addition, piled wrought iron has zones of very great corrosion resistance, and these are due to selective oxidation of the surfaces of the pieces composing the pile, with subsequent enrichment in copper and nickel. The corrosion of wrought iron, therefore, differs from that of iron and steel in being zonal. Superior resistance is obtained with wrought iron only if advantage can be taken of the presence of slowly corroding layers.

A Computer for the Steel Industry

BISRA is to instal a Ferranti " Pegasus " electronic digital computer next year. It will be the first machine of its type to be used in the iron and steel industry, although several of the larger steel companies have placed orders for other computers.

The value of a machine of this type in research needs no emphasis. With its aid, statistical analyses, which form so important a part of much industrial research, can be performed more rapidly and more thoroughly ; and numerical solutions can be obtained for many problems hitherto intractable because of the enormous amount of labour entailed.

Although many aspects of research will benefit from

(*Continued on page* 182)

The Equipment of the British Non-Ferrous Metals Research Association

By E. C. Mantle, M.Sc., A.I.M.,
Chief Liaison Officer of the Association

OUR previous contributions to METALLURGIA have dealt with the work of the Research Association, including highlights from the research programme and the technical services provided for members. In the present article it is proposed to describe the facilities available to the Association, the tools with which the work is carried out. The laboratories and their equipment are well known to most members of the B.N.F.: about 300 visit Euston Street each year, apart from those attending committee meetings. The laboratories also receive a considerable number of visitors from overseas, many of whom are surprised at the comprehensive facilities available.

While no major items of heavy equipment have been installed within the last two or three years, apparatus has continued to be added to cope with fresh requirements, and in several instances new uses have been found for old-established pieces of metallurgical apparatus. Probably nowhere else in the country is there a more complete range of metallurgical equipment on one site.

The Laboratory Buildings

Although the laboratories of the Association occupy a comparatively small site in Euston Street, they have a floor area of 45,000 sq. ft. and are literally crammed with equipment and house a total staff of about 160. They have been extending on their present site since 1930. By today's standards they are not a show place: their arrangement is largely conditioned by the buildings, and is far from ideal. But this has not been allowed to hinder the growth of the work of the Association nor prevented additions to the equipment. When fresh work has to be undertaken, or new apparatus is needed, somehow a corner is found where a bit more can be squeezed in. This state of affairs cannot, of course, go on indefinitely, and periodically the laboratories have had to burst out into adjoining properties.

The laboratory block originally occupied in 1930, is now the centre of the group of buildings. It suffered a disastrous fire during the war, but was rebuilt within the old shell and re-opened in 1950, to house the metal working equipment, part of the General Metallurgy Section and the administrative staff. Just before the war, a new and by those standards entirely modern laboratory block was built. It was opened in 1937, and at present houses the chemical laboratories, the spectrographic and physics laboratories, the mechanical testing section, and also the information department, library and council room. These two buildings are joined by the foundry, which has, however, had to be considerably extended in recent years into adjoining premises. Immediately after the war, a considerable increase in the Association's work resulted in the expansion of the laboratories into two further neighbouring buildings—originally old factories—and even after the original block destroyed in the war was recommissioned, it was still found necessary to house a considerable part of the work in these old buildings.

The position has now been reached when the laboratories are once more outgrowing their shell. This is partly the result of increasing demands for research in existing fields, and partly the result of an extension of the Association's work into wider fields such as the metallurgical problems associated with nuclear power. Council is at present giving urgent consideration to this question. One possibility is the erection of another new laboratory block on a vacant site in Euston Street adjacent to the existing building; expansion on the present site will then have reached its limit.

Organisation of Research Department

Although the research programme is selected through a committee structure based on the different divisions of the industry, the research work within the laboratories is carried out in sections dealing with different branches of metallurgy rather than with different groups of alloys. There are now seven sections of the Research Department each with a senior research worker in charge of a group of investigators and the necessary assistants: Melting and Casting, General Metallurgy, Mechanical Testing, Corrosion, Metal Finishing, Physics and Chemistry. In addition, the laboratories are served by a well-equipped workshop.

These sections do not, of course, work in water-tight compartments, each is expected to give service to other sections when called upon, and the facilities of all the sections are available to help in the solution of technical problems submitted by member firms through the Liaison Department's confidential technical enquiry service.

Foundry Work

The foundry contains equipment for making sand and chill castings in all the non-ferrous alloys. A large part of the work is concerned with sand castings, and there are two small sand mills, a core-drying oven and the usual items of sand-testing equipment. In the past two or three years much attention has been given to new foundry techniques. In collaboration with the Association of Bronze and Brass Founders, surveys have been made of the applications of both shell-moulding and the CO_2 process to non-ferrous foundry work. Lack of information on certain aspects is being made good by experimental work. Some time ago a small shell-moulding machine was built in the workshop, and apparatus has also been installed for making cores and moulds by the CO_2 process.

Seven gas-fired furnaces ranging in capacity from 10 to 200 lb. form the backbone of the melting equipment. The largest is a bale-out furnace installed originally for

Fig. 1.—Hand operated machine built in the Association's workshop for experimental work on shell moulding.

work on the control of gas content of aluminium die-casting alloys. It has since been found particularly useful in research on the removal of impurities from copper during refining, where it has been necessary to hold charges molten for long periods. In addition, there is a high frequency melting unit of the spark gap type, various resistance furnaces for special purposes, and a vacuum furnace capable of melting and casting about 20 lb. of metal. This furnace was built in the Association's workshop. It consists essentially of a large chamber inside which the crucible is supported and heated by a surrounding molybdenum wire grid. There are external controls for making additions to the melt and for pouring the metal into an ingot mould without breaking the vacuum. The furnace can operate at temperatures up to about 1,400° C., and vacuum down to 10^{-4} mm. is obtainable.

Since the foundry has to provide other sections with casts of experimental alloys, it has a large number of chill moulds of different shapes and sizes, and is also equipped for making castings by the Durville process and for making small continuous castings.

Elaborate apparatus installed for work on the solidification of castings and for measuring the rate of heat extraction with different kinds of moulding media, is housed in a separate instrument room. This apparatus includes two amplifiers and two recorders and is capable of scanning up to thirty thermocouples, sited either in different parts of a solidifying casting or in the mould, at the rate of eight per second.

Gas/metal reactions and the effect of gas absorption on the soundness of castings have featured prominently in the researches over the past twenty years. The extent of gas pick-up is usually assessed from the density of a sand-cast test bar, and with a high speed balance specially adapted for the purpose it is possible to do the weighings for a density calculation in about two minutes. For light alloys, the B.N.F. reduced pressure test has been very useful for a qualitative assessment of the gas content of melts before casting. This apparatus, in which a dip sample is allowed to solidify under a low pressure, is now manufactured commercially and is in use in a number of industrial foundries. More recently, the Melting and Casting Section has obtained a Ransley gas tester, which enables a direct measurement of the hydrogen content of a melt to be obtained almost instantaneously, and this should considerably facilitate future studies of gas pick-up and degassing processes.

General Metallurgy

This Section is equipped to deal with microscopical metallography, heat treatments, and problems concerning gases in metals, as well as the more specialised requirements of individual researches. The Section is also responsible for the operation of the metal working shop in which experimental materials can be prepared in wrought form and their working behaviour examined. So much metallographic work has to be handled that the metallographic laboratory occupies three separate rooms: one for rough preparation of specimens and mounting, one for grinding and polishing, and a microscope room, with adjoining dark room, for final examination. Both the mounting press and the automatic polishing machines were designed and constructed in the workshop and have been widely copied. Quite a lot of specimens, particularly sections through electroplating and galvanized steel, are polished with diamond dust. For the general run of work, however, *gamma* alumina specially prepared in the laboratories is used.

There are several modern bench microscopes, a low power stereoscopic microscope for the examination of fractures, corroded surfaces, etc., and three Vickers projection microscopes for photographic work. Stereoscopic photography has been introduced recently for recording fractures, corrosion-pitted surfaces, etc. One of the projection microscopes is frequently used for the mapping of surface contours by Tolansky's multiple beam interference technique.

Microhardness measurements are made with a diamond indentor simply adapted to fit into one of the bench microscopes. Measurements of particle sizes, coating thicknesses, etc., are other jobs which the Section is frequently called upon to carry out.

The laboratory for gas extraction and analysis is probably unique in the range of facilities available. Gas is extracted from solid metal samples in various ways, such as heating the metal specimens or drilling into blisters or gas cavities in the specimens, and gas mixtures in quantities down to about 0·001 cc. can be analysed completely. Simpler apparatus is available for the routine determination of hydrogen in metals, and there is vacuum fusion apparatus for the determination of the oxygen and nitrogen contents of the more refractory metals such as titanium and zirconium. A hydrogen reduction apparatus developed by Baker is used for the determination of trace quantities of oxygen in easily reducible metals such as copper and lead.

For the production of experimental alloys of titanium and zirconium, there is an arc furnace with a water-cooled hearth and an argon atmosphere. A Kroll graphite resistance vacuum furnace used in the early days of titanium metallurgy still finds some uses, and there are also a large number of small heat treatment furnaces covering temperature ranges up to 1,200° C. Some are adapted for working with controlled atmospheres or high vacuum, and temperatures are recorded on a central potentiometric recorder.

The metal-working shop contains on a small scale all the main pieces of equipment used for fabricating cast

material into wrought products. There is a 12 in. × 12 in. two-high rolling mill, a 500-ton press used for both forging and extrusion, a 50-ton press for powder metallurgy, a draw-bench, a power hammer, and a simple drop-hammer for assessing forging characteristics. The rolling mill has recently been used for an investigation into the production of copper strip by the compacting of powder by rolling. The powder is fed into a hopper on the entry side and metal strip comes out on the other side to be sintered and further processed to develop the optimum properties. A pit below the 500-ton press enables short lengths of extrusions to be made. Until recently only lead alloys had been extruded, but a press assembly is now available for research work at present being carried out on high-strength aluminium alloy extrusions.

Creep and Fatigue Testing

It goes without saying that all the usual run of mechanical testing equipment is available, but modern engineering design calls for accurate predictions of the long-term behaviour of structural material, which cannot be based on ordinary tensile properties. It is not surprising, therefore, that the Association's work on mechanical testing has concentrated largely on the creep resistance and fatigue properties of metals. There are 76 creep testing units of a type designed at the laboratory some years ago* : they are compact, robust and simple to operate. Tests can be made up to 750° C., the temperature control being to ± 1° C. or better, and the sensitivity of strain measurement on the standard 5 in. gauge-length specimen used is 2×10^{-5} strain. Creep data have been determined with these units for several aluminium alloys, for high-conductivity copper, aluminium bronzes and many other copper alloys. At present, many units are occupied with tests on special titanium and zirconium alloys being developed in the laboratories.

Fatigue testing, particularly of aluminium alloys, aluminium bronzes, and, more recently, titanium alloys, has been given considerable prominence. Twelve rotating load machines of unique design† are in constant use. They are very versatile, accommodating either round or flat specimens, operating up to 750° C., and adaptable for corrosion fatigue testing. Four Wohler fatigue machines are also in constant use, some having been adapted for a progressive loading fatigue test by which the approximate endurance limit can be found in a few hours. There are also three small variable-throw crank machines for fatigue testing strip materials. At present a considerable amount of the work is concerned with examining the effects of notches and other stress raisers, and it is proposed to extend the work to the examination of the fatigue strength of joints, for which a large (± 10 tons) direct stressing machine is to be installed.

Rather different techniques have to be used when studying lead alloys : one of the long-term researches is concerned with the development of improved lead alloys for cable sheathing, where creep and fatigue resistance and stability of structure are of great importance. Since many lead alloys readily undergo recrystallisation as a result of only moderate temperature rises, this work is done in a room controlled at 20° C. The room has a capacity of 150 creep specimens as well as several machines for fatigue testing. Cable sheathing may be subjected to fatiguing action at a variety of frequencies, and bending machines are available for tests at 3,000 cycles per minute, 1 cycle per minute and 1 cycle per hour. Much of the material used for this work is extruded under carefully controlled conditions in a small extrusion press which is operated by the compression side of a hydraulic Amsler tensile testing machine.

Fig. 2.—Vacuum sealed drilling apparatus for extracting gas from blisters in metal sheet.

The Izod impact machine also has other uses. It has been modified to break a small tensile test piece, the apparatus being so arranged that the tests may be carried out over a range of temperatures. Measurement of the energy to fracture, together with the elongation of the test piece, give a good guide to the hot-working capabilities of alloys.

Corrosion

The usual apparatus is available for electrochemical measurements, and the recording of electrode potentials and corrosion currents have been used from time to time in the course of various investigations. Generally, however, it has been found more profitable to devise tests to simulate in the laboratory, as far as possible, the conditions actually encountered in service. A good example of this is the May Jet Impingement Test, which has been used to such good purpose in the development of alloys for marine condenser tubes. Severe localised corrosion can occur at points where air bubbles entrained in the sea-water stream impinge on the tube walls, and the May test exactly reproduces these service conditions. A number of test rigs are in constant use in a room set aside for work on sea-water corrosion. In some, the very aggressive conditions met with in heat exchange plant operating on polluted estuarine water are reproduced by regularly doping the sea-water with hydrogen sulphide. In all the work on marine corrosion, natural sea-water is used.

* METALLURGIA, 1950, **42**, 189–196.
† METALLURGIA, 1948, **38**, 247–254.

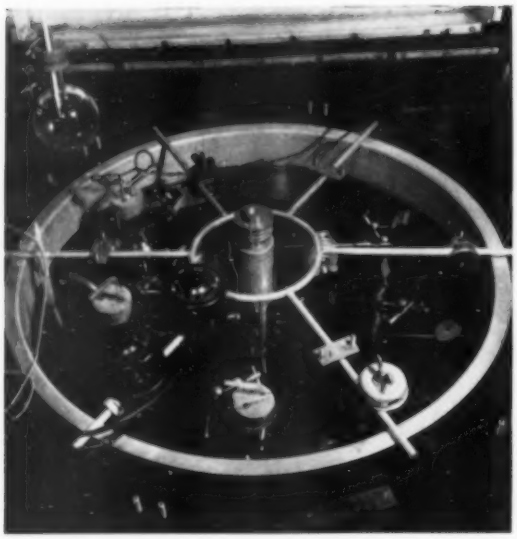


Fig. 3.—Thermostatically controlled oil bath for corrosion experiments involving electrode potential measurements.

In recently completed work on the development of heat exchanger tubes for gas turbines, a test was again devised to reproduce service conditions. In this case, specimens were heated in a tubular furnace through various cycles up to 600° C. and exposed to a stream of moist sulphur dioxide, to which in some cases traces of hydrochloric acid were added, these being the main corrosive agents in the turbine exhaust gases. For current work on the corrosion of fittings in supply waters, test rigs in which conditions resemble domestic hot water systems are being used, water being imported for the tests from areas where it is known the conditions are aggressive.

A rather different approach was used in the work leading up to the solution to the problem of the pitting corrosion of copper water pipes in some areas. Much use was made of artificially produced anodic corrosion cells, and the measurement of electrode potentials and corrosion currents have featured largely in the Association's work on the behaviour of galvanized steel in water. Usually such work is later verified by field trials, which play a large part in the work of the section. Several sites are used to test the behaviour of non-ferrous metals in supply waters, and there are also a number of sites where specimens are buried underground. The Section possesses a marine corrosion station at Hayling Island, and it is in some ways convenient that the roof of the laboratories provides a fairly severe " industrial atmosphere " site.

The stress-corrosion susceptibility of some aluminium alloys is one of the most important researches being tackled. A large room maintained at 85% relative humidity is set aside for this work. Much use is made of tensile test pieces stressed in frames by calibrated springs and sprayed with salt solution. This room is also convenient for other tests where resistance to humid conditions has to be assessed, although there is also a separate humidity cabinet.

Electroplating

Before the war, work on electroplating was carried on extramurally, and it is rather less than ten years since a plating shop arranged for work on a semi-production scale was installed. The shop must be one of the largest experimental plating plants in existence, and it has had in operation for several months two pilot scale bright nickel plating lines, with all the necessary cleaning and swill tanks, for processing bumper bar over-riders under conditions simulating industrial production.

Such comparatively large scale working is necessary only when it is essential to reproduce industrial conditions, either to study industrial processes in great detail or else to see how a new process will behave when worked on a large scale. At present, a new crack-free chromium plating solution developed by the Association* is being tested in this way. However, much work is possible in smaller tanks, of which several are available, and these are also used frequently for examining electroplating problems received from members.

In an industry which has so far been largely empirical, the development of control and acceptance tests can add greatly to efficiency. Concentration on these aspects has been the main trend of the work on bright nickel plating. Tests such as the Hull Cell for throwing power and the Brenner and Senderoff Contractometer for stress measurement have been used, and in addition, a simple bending test suitable for use as a routine method of maintaining a check on the ductility of the deposit has been devised.

One advantage of conducting research on metal finishing within comprehensive metallurgical laboratories is that a wide range of techniques not usually associated with electrochemical laboratories can be brought to bear on any problem. Extensive use is made of metallography for examining the structure of deposits, their adherence and any defects present. Careful metallographic work will often tell at what stage a plating defect arises.

* Patent Application No. 26365/55.

Fig. 4.—The Brenner and Senderoff contractometer used for measuring the development of stress in deposits during electroplating.

X-ray and electron diffraction techniques are at hand for examining the crystal structure of deposits, spectrographic analysis can be used for examining both deposits and solutions for metallic impurities, while the analytical laboratories have the most advanced equipment.

New Analytical Procedures

The analytical laboratories have given considerable help to the electroplating section, particularly in the research on bright nickel plating. The determination of the organic constituents in these solutions presented a difficult problem, which was solved by applying the technique of spectrophotometry to ether extracts of these organic compounds. Although these extracts are not coloured, they give absorption curves in the ultraviolet region, which could be measured on one of the laboratory's spectrophotometers. Two of these are available, the smaller (covering only the visible spectrum) being used for more routine colorimetric analyses.

The Chemistry Section has the task of keeping abreast of all new analytical techniques, and of deciding whether they have useful applications in the non-ferrous metals industry. It has made a special study of physico-chemical methods and is equipped for polarography as well as spectrophotometry. Electrochemical methods of analysis are used extensively, the mercury cathode separation having been employed for many years, particularly for determining aluminium in copper alloys.

An interesting new departure is the application of ion-exchange resins to the analysis of metals and electroplating solutions. By means of an ion-exchange column it is often possible to separate interfering ions from a solution, and so greatly simplify an analysis. For example, greenish nickel plating solutions can be made colourless by removing the nickel ion, thus allowing the acid radicals to be determined easily, and in chromium plating solutions separation of the hexavalent chromium anion from the trivalent chromium cation enables the latter to be determined more accurately. A large ion-exchange column containing a mixture of both anion and cation exchange resins was built recently for preparing water for the analytical laboratories of greater purity than was formerly made in the conventional laboratory stills.

Spectroscopy and X-ray Crystallography

The years immediately following the war were a period when there was marked emphasis on physical metallurgy, and the Physics Section was largely equipped then. The Association had, of course, done pioneer work in spectroscopy many years before, and in this the laboratories were already well equipped. At the moment, there are three separate rooms devoted to spectrographic analysis, as well as a special dark room and a small additional laboratory for preparing samples for the solution method of spectrography. This latter is becoming increasingly important for, apart from other considerations, it overcomes the difficulty of collecting sets of standards, since it is only necessary to prepare synthetic solutions of known composition. About six different techniques of solution spectroscopy are in use, but the most common is the porous graphite cup, and a small machine has been built which makes about 200 of these cups in an hour.

The spectrograph in most constant use is a Medium Quartz which is used in conjunction with a B.N.F. Source

Fig. 5.—An X-ray diffraction camera with rotating copper target built in the Association's workshop.

Unit, but an ARL Production Control Quantometer is also in general use, and for work where high dispersion is required there is a Littrow spectrograph. Incidentally, it is interesting to note that several years ago this was adapted to give direct readings using photo-electric cells, and proved of considerable value in studying source characteristics.

The Production Control Quantometer, one of the first to be installed here, was a model made specially for studying its application to the analysis of copper and copper alloys. It was, of course, then already well established in the United States for analysing aluminium and steels.

The physics laboratory itself contains equipment for X-ray diffraction, electron diffraction and an electron microscope. There are two X-ray sets for crystallography. One is a commercial model of the type normally used for X-ray crystallography, the second was made in the laboratory workshop and is of unusual design, with a rotating water-cooled copper target. It enables exposure times to be considerably reduced and has been invaluable in relieving congestion in the section. These X-ray sets are used for the determination of preferred orientation and grain size, for investigating recrystallisation, for assessing the extent of cold work, and for measuring the parameters of solid solutions, as well as for the identification of the chemical composition of materials such as corrosion products. They are also used for micro-radiography.

The electron diffraction equipment was designed and built in the laboratories, and is arranged so that a beam of electrons impinges at a glancing angle on the surface of a specimen in a horizontal position, producing a diffraction pattern which can be photographed. It is most suitable for the examination of thin surface films on metals.

The electron microscope was purchased about ten years ago at the time when these instruments were some-

(Continued on page 182)

The British Steel Castings Research Association

By A. H. Sully, M.Sc., Ph.D., F.Inst.P., F.I.M.

Director of the Association

THE most important development in the evolution of the British Steel Castings Research Association which has taken place in the year under review, has been the construction of its new Research Station in Sheffield. The buildings are now virtually completed and the Association will transfer from its present premises at Broomgrove Lodge, Sheffield, on or about November 1st. Fig. 1 is a drawing of the frontage of the new laboratories and offices, which are at East Bank Road, Sheffield. Substantial progress has been made with the engagement of staff for the new Station, which will be fully operational by the end of 1956. An official opening ceremony is planned for the Spring of 1957.

The Association's programme of investigation in the past has been limited in scope by the lack of adequate facilities for experimental work, and, although substantial progress has been made with several investigations of considerable importance to the steelfounding industry, there is no doubt that the occupation of the new Research Station, together with the accompanying considerable expansion in the number of staff engaged in experimental work, will not only materially quicken the tempo of the Association's research, but will also enable new projects of importance to the industry, to which adequate attention could not be given in the past, to be included in the investigational programme.

New Research Station

The main feature of the new laboratories is a crane swept foundry bay 90 ft. × 40 ft. in size. This houses two melting furnaces : a small H.F. melting unit of 40 lb. capacity and a Junkers carbon resistor rod furnace of 6 cwt. capacity. The latter type of furnace is little known in this country, although used extensively on the Continent. Experimental trials carried out by the Association's staff in Germany have shown that this furnace can be used not only to melt but also to refine steel. It can be operated with a basic lining and slag, and with gaseous oxygen injection. It can, therefore, be used for experimental work on steelmaking, and for this purpose has certain advantages over a small electric arc furnace.

The foundry bay provides adequate facilities for sand preparation, moulding, and the cleaning, fettling and repair of castings. On either side of this bay there are single storey bays which house the machine shop, mechanical test laboratory, chemical, physical and metallurgical laboratories and dark rooms. A laboratory for investigations of dust assessment and control is separately housed. This will be provided with a dust tunnel in which dust suspensions of a known and constant concentration can be maintained. A further building accommodates the Library and Information Section, administrative offices and a conference room.

Dust Control Conference

A noteworthy feature of the Association's year was the Conference held at York on October 13th–14th, 1955, on the subject of "Steel Foundry Dust Control and Ventilation." This subject is of considerable importance to the foundry industry at the present time as a consequence of the issue of the new Iron and Steel Foundry Regulations, which call for a high standard of ventilation in foundries. The Conference was outstandingly successful and was attended by representatives of 85% of the members of the Association. Eight papers were presented, on dust control on grinding machines and portable fettling tools, the sampling and assessment of airborne dusts, the efficiency of dust collectors, foundry ventilation, and heating and dust control at foundry

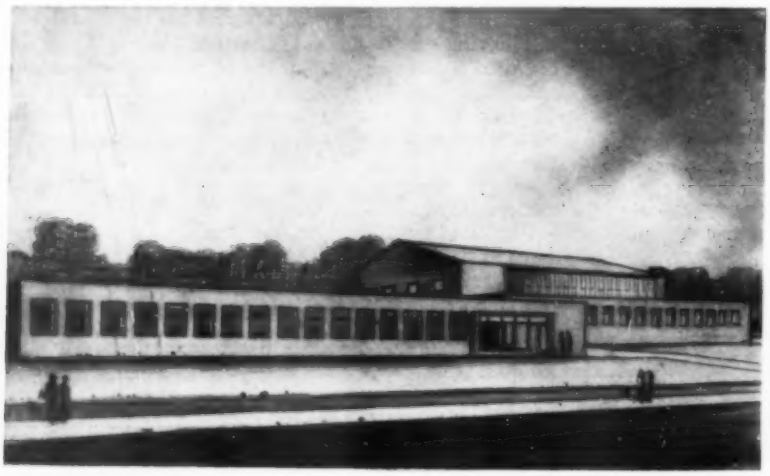


Fig. 1.—Artist's impression of the frontage of the new research station.

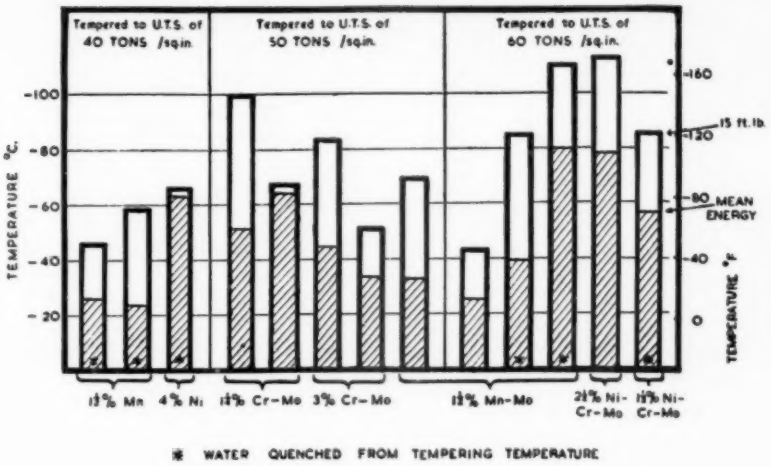


Fig. 2.—The low temperature properties of commercially produced quenched and tempered alloy cast steels compared on the basis of results obtained using the Charpy V-notch impact test. The temperatures indicated are those associated with the 15 ft.lb. and the mean energy levels.

knockouts. The Conference was attended by Sir George Barnett, H.M. Chief Inspector of Factories, and by Mr. J. H. Wigglesworth, Secretary of the Iron, Steel and Metal Dressers' Trade Society, both of whom delivered opening addresses.

The Conference Proceedings and Discussion, comprising some 55,000 words and 90 illustrations, were published and distributed to members within five months of the Conference taking place, and constitute a valuable handbook summarizing existing knowledge on this very important topic.

A similar Conference on the subject of "Steel Foundry Moulding Materials," will be held at York in October, 1956. Such conferences, organised on a national basis, constitute an important channel of communication between the Association and its members. By this means it is possible to provide members with opportunities for discussion of the results of the Association's investigations. To supplement the Association's own work, contributions are also invited from member firms and from authorities outside the steel founding industry, including the representatives of other Research Associations with similar interests.

Research

During the year under review, substantial progress has been made in a number of research investigations and other projects. Of these, the following deserve special mention :—

Metallurgy

Properties of Cast Steels at Low Temperatures

In view of the increasing preoccupation of users of steel castings with impact strength at low temperatures, an investigation has been undertaken to provide data on the low temperature impact properties of commercially produced steel castings. The tests carried out have enabled the Charpy V-notch transition curves for each steel to be determined in various conditions of heat treatment. A smaller number of Charpy keyhole-notch tests was made in order to determine the temperature associated with a 15 ft. lb. keyhole-notch value, which is the test figure required in most American specifications for steels for low temperature service. Measurements have been made on carbon steels and on low and medium alloy steels, and the results have been published in two Reports issued to members of the Association.

For plain carbon steels, it has been demonstrated that, as for wrought steels, high low-temperature impact values are favoured by maintaining a high manganese/carbon ratio. It has also been shown that in the as-cast condition the impact properties are inferior to, and more variable than, the properties of annealed or normalized cast steels. In general, the best low temperature impact properties are obtained in steels which are both annealed and normalized.

For low and medium alloy steels, the highest impact resistance at low temperatures is developed in fully hardened and tempered steels. The importance was also demonstrated of avoiding temper brittleness in steels known to be susceptible to it, by water quenching from the tempering temperature. These conclusions are exemplified by results on a 1½% manganese steel, which are summarized in Table I.

The influence of tensile level, as controlled by the tempering temperature, on the low temperature properties of hardened and tempered steels was also investigated. The general effect of decreasing the tempering temperature (increasing the tensile level) was found to be two-fold, namely :—

(*a*) to lower the maximum impact value ;

(*b*) to raise the transition temperature.

The results obtained on hardened and tempered steels are compared in Figs. 2 and 3. Fig. 2 summarizes and compares the results obtained on the various steels obtained from different suppliers on the basis of the temperature associated with the 15 ft. lb. Charpy V-notch impact value, and with the mean energy level (i.e., the

TABLE I.—CHARPY V-NOTCH RESULTS ON A 1½% MANGANESE STEEL, ASSESSED IN TERMS OF THE PERCENTAGE OF BRITTLE (CLEAVAGE) FRACTURE EXHIBITED. THE ADVANTAGE TO BE GAINED BY WATER QUENCHING THIS STEEL FROM THE TEMPERING TEMPERATURE IS DEMONSTRATED.

Heat Treatment	Percentage of Brittle Fracture at	
	20° C.	— 20° C.
Normalized and tempered (air cooled from tempering temperature)	60	90
Quenched and tempered (air cooled from tempering temperature)	0	80
Quenched and tempered (water cooled from tempering temperature)	0	30

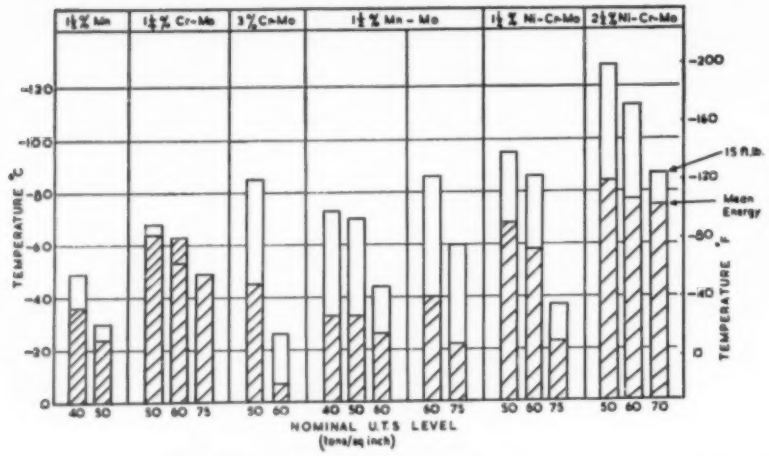


Fig. 3.—Comparison of mean temperatures to give 15 ft. lb. and mean energy using the Charpy V-notch impact test, for commercially produced steels hardened and subsequently tempered to different tensile levels.

impact value which is the mean between the maximum value above the transition and the minimum value below it). Fig. 3 illustrates for each type of steel the effect of tempering to various tensile levels on the mean temperature for the 15 ft. lb. and mean energy criteria.

Apart from their general scientific interest, the data which have been collected will prove to be very useful for the purpose of framing specifications for steels for service at low temperatures.

Magnetic Properties of Cast Steel

Substantial progress has been made with an investigation to determine the influence of heat treatment on the magnetic permeability of cast carbon steels of differing carbon content. Tests have been made on a series of steels of carbon content ranging from 0·10% to 0·35%, in the as-cast, normalized and annealed conditions. For any given carbon content, the measure of improvement in magnetic permeability resulting from annealing, as compared with normalizing, has been demonstrated. The results of this investigation are illustrated by Fig. 4, which shows permeability plotted against flux density for a range of steels of differing carbon contents in the annealed, normalized and as-cast conditions. Mechanical properties of the steels were also determined.

In order to take advantage of the superior magnetic properties of fully annealed material, while keeping furnace time and fuel consumption to a minimum, data have been obtained to determine the temperatures at which furnace charges may be withdrawn and air cooled, without impairment of the properties conferred by a full annealing treatment. Results indicate that decreasing the withdrawal temperature from one consistent with normalizing to one of full annealing, progressively improves magnetic permeability, with the exception that material withdrawn at 700° C. and air cooled is slightly superior to the fully annealed material at higher magnetizing fields (above 100 Oersteds). The completion of this investigation by a determination of the effect of isothermal annealing and a further short study of the effect of small quantities of residual alloying elements on magnetic permeability, is in hand.

Foundry Practice and Moulding Materials

Carbon-Dioxide : Sodium-Silicate Process for Hardening Moulds and Cores

This process is being used on an increasing scale in some steel foundries as an alternative to dry sand moulding and normal oil sand core practice, since it has the advantages of being quicker and eliminating the necessity for stoving moulds and cores. An investigation of the critical factors in the process has been carried out for the Association at the Department of Refractories Technology at Sheffield University under the direction of Professor J. White. Among factors which have been

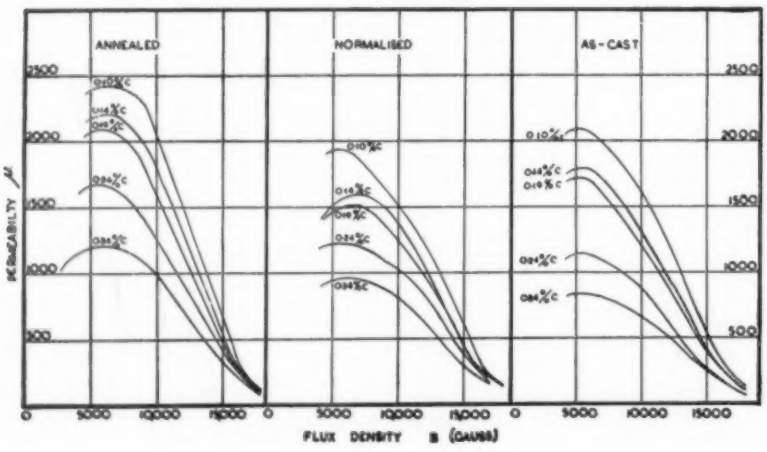


Fig. 4.—Curves showing the magnetic permeability plotted against flux density for a range of carbon steels in the annealed, normalised, and as-cast conditions.

studied are the effect of the $Na_2O : SiO_2$ ratio and of the solids content of the sodium silicate on the rate of hardening on gassing with CO_2.

It has been established that the rate of hardening decreases with increasing alkalinity of the sodium silicate, whereas variation in the solids content within the range of normal commercial silicates has comparatively little effect. With highly alkaline silicates, however, considerable further hardening takes place on standing after CO_2 treatment, whereas with the less alkaline silicates standing time has little effect. This increase in hardness with standing time of sands bonded with alkaline silicates may take place over a number of days, and the final strengths reached may be very high.

The effects of organic additions, which are primarily intended to give increased collapsibility, on the bonding and bench life properties of sands bonded with commercial silicates have also been investigated. These additions consisted of sugars, both cane and syrup, and cereals, both starch and dextrine. They had little effect either on bonding properties or on the bench life of the silicate mixes. Determinations of the hot strengths of silicate bonded sands show that the strength varies in a complex manner. In the range up to 800° C., two strength peaks are observed, one at 250° C. and one at 530° C., both being followed by a rapid fall in strength. This behaviour is due to rapid loss of residual water and hardening of the bond in the range up to 260° C. and from 360° C. to 590° C., respectively, whilst the falls in strength occur when the rate of loss of moisture with temperature slows down and the bond softens.

Further work on the hot strength properties of silicate bonded sands is in progress, in which it is intended to determine what effect various organic additions have upon the rate of collapse at elevated temperatures.

Data Sheets on Moulding Sands

As a guide to members, and to fulfil a long standing need, the Association has compiled in the form of data sheets the main properties of available steel foundry moulding sands of British origin. So far, information on 70 sands has been obtained. The properties which are given for each sand include size grading, refractoriness, grain shape, and green and dry strengths. Wherever possible, some estimate of the consistency of properties over fairly long periods of time has also been given.

Mould and Core Bonding Agents

The Association regularly examines new mould and core bonding agents in order to assess their value to the steelfounding industry. Recently, a Report has been issued which summarises the properties of 52 bentonites and kaolinitic clays which have been examined in the past three years.

Recent materials examined include the " cold setting " type of core binders, which have found increasing application in foundries on the Continent. The Association's evaluation of these suggests that they may find application in British foundries also, especially for purposes where cores need to be made to very accurate dimensions.

High Temperature Properties of Mould Refractories

Work on this investigation, which is financially supported by the Association, has been in progress in the Department of Refractories Technology of Sheffield University under the supervision of Professor J. White.

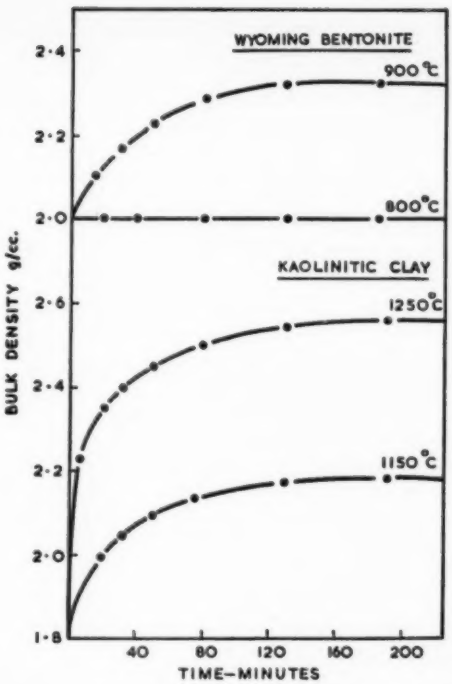


Fig. 5.—Curves showing the change of bulk density on heating pellets of Wyoming bentonite and of a kaolinitic clay at various temperatures.

The investigation has been concerned with a study of the effects of heat on the properties of clay-bonded sands, including the nature of the mechanism by which the peak on the conventional hot strength curve is developed. The results have confirmed work carried out by the British Cast Iron Research Association, which has shown that no peak occurs with short times of heating. It has been shown that the peak develops as a result of a time-dependent sintering process following thermal decomposition of the clay. The sintering process is independent of the decomposition process, but is related to the ultimate refractoriness of the clay ; e.g., bentonites have a higher decomposition temperature than kaolinites, but sinter and develop peak strengths at lower temperatures than the latter. Both decomposition rates and sintering rates have been measured as functions of temperature, and the results of this study indicate that the times involved in development of the peak are such that they are likely to be of significance with respect to the behaviour of sand under actual casting conditions.

The latter point is illustrated by Fig. 5, which shows the change of bulk density on heating pellets of Wyoming bentonite and of a kaolinitic clay at various temperatures. It will be seen that, whereas the former shows an appreciable increase in bulk density (amount of sintering) on heating at 900° C., a temperature of 1,150° C. is required to produce a corresponding increase in a comparable time in the case of the kaolinite.

Work on the rate of decomposition of clays has been extended to include studies of the effects of compaction, and of wetting and subsequent drying to simulate the condition of the clay in a milled and rammed sand. The results show that while compaction decreases the decomposition rate at a given temperature to a significant

extent, a much more marked retardation occurs in the case of swelling bentonites which have been agglomerated by wetting and drying. With non-swelling clays, e.g., kaolinite and non-swelling bentonite, on the other hand, the latter treatment has little or no effect on the rate of decomposition. This should have a bearing on the relative life of swelling and non-swelling bentonites in practice.

Further work will be concerned with the effect of such temperature-dependent changes on the interaction of the sand with molten metal.

Steelmaking

Oxygen Injection in Basic Electric Steelmaking Furnaces

Using an accurate integrating flowmeter, the Association is carrying out a survey of the utilisation of oxygen in basic electric steelmaking in member foundries. This survey, which will lead to the establishment of conditions for the more efficient use of oxygen, is being combined with a study of slag and metal composition, and of the hydrogen and nitrogen content of the steel before and after oxygen blowing. A study of the results is being made in the light of existing knowledge of the physical chemistry of steelmaking, in the hope of providing guidance to member foundries on the improvement of steelmaking practice.

Plant Engineering and Industrial Health

A close watch is being kept on all new developments in plant and equipment for foundry use, and B.S.C.R.A. staff are engaged in studies of moulding sand compaction which will contribute to the design of improved moulding machines. Studies of dust suppression continue to occupy an important place in the programme of investigation, and during the year an improvement has been made in the B.S.C.R.A. integral exhaust system for pedestal grinding machines which has led to a greatly increased efficiency.

International Meeting of S.G. Iron Licencees

The Sixth International Meeting of S.G. Iron Licensees, convened by The Mond Nickel Co., Ltd., in conjunction with Metallgesellschaft A.G., was held from August 29th to August 31st in Essen. There was a record attendance of over 270, and those taking part were representative of 19 countries, in all parts of the world. At the Technical Sessions, the chair was taken by Dr. L. B. Pfeil, Director of The Mond Nickel Co., Ltd., supported by Dr. W. Overath of Metallgesellschaft A.G., and Dr. H. Timmerbeil of Knorr-Bremse G.m.b.H., the President of the German S.G. Iron Producers' Association.

The wide range of the 23 papersoffered for discussion demonstrated continuing progress in manufacturing methods and the increasing importance of S.G. iron in industry. Particular interest was shown in a new nickel-free calcium-silicon-magnesium-iron pre-alloy for the production of spheroidal graphite in cast iron. This material, which is known as M.G. 55 Alloy, has been developed as the result of co-operative investigations by Metallgesellschaft and Süddeutsche Kalkstickoff-Werke. It has already been subjected to comprehensive tests in large-scale foundry conditions, and is proving highly satisfactory, both technically and from an economic standpoint. It is hoped that supplies will shortly be commercially available to licensees.

Users of S.G. iron reported experience in various branches of the engineering industries, where the adoption of S.G. iron castings has resulted in longer service life, improved functioning of components, more favourable strength/weight ratio, and other advantages. The reports made at the meeting received interesting confirmation from the exhibits shown at the G.I.F.A. (Internationale Giesserei-Fachmesse), where, at a number of stands, leading firms were showing S.G. iron castings for use in both heavy and light engineering industries.

An important feature of the Conference was a series of works visits. On the first day the delegates were received by Schmiedag A.G., Werdohl, where there was a demonstration of production of hollow crankshafts for the automotive industry. The large quantities of those castings awaiting dispatch made a most impressive display. At the foundry of Gebrüder Eickhoff, Bochum a sealed ladle of the S.K—B. type was seen in operation. On the morning of the second day a tour was made of the laboratories and the foundry of F. Krupp A.G.; during this visit the Krupp basic hot-blast cupola was shown in operation and the use of M.G. 55 Alloy was demonstrated.

The Equipment of the British Non-Ferrous Metals Research Association

(*Continued from page* 177)

thing of a novelty. Initially, it was obtained so that the Association could determine whether this method of examination was likely to prove useful in metallurgical work. The development of suitable techniques occupied much time initially, but these are now fairly well established and the instrument has continued to be used in the laboratories, mainly for resolving metallographic problems where there is doubt about the evidence presented by examination under the ordinary optical microscope.

In this account, it has been possible to mention only the more important apparatus with which the laboratories are equipped. Many interesting pieces of apparatus have had to be omitted. Enough will have been said to indicate the important part played by equipment made in the workshop, and a tribute is due to the workshop staff for the skill and ingenuity with which they interpret the ideas of the scientific staff.

The British Iron and Steel Research Association

(*Continued from page* 172)

the assistance of the computer, and highly trained staff will be freed from routine work, its most important function will be to act as a pilot plant for studying the use of computers throughout the industry.

The potential value of computers as an aid to management is great. They can, for example, be used for production control, costing and stores control. The experience gained by BISRA staff in operating the new machine will eventually be available to member firms considering the installation of similar equipment. It will also be possible to assist in training firms' staff, and in advising on operating and programming methods most suited to conditions in the industry.

Acheson Centenary

Graphite and Carborundum Pioneer

"—He inspired all who came in contact with him. I am proud to have known him. As long as I live I shall remember him as a man who combined a most fertile brain with great strength of conviction and well directed action in whatever he undertook—to his intimates displaying qualities of heart and sentiment which endeared him to those who learned to know him."—L. H. Baekeland.

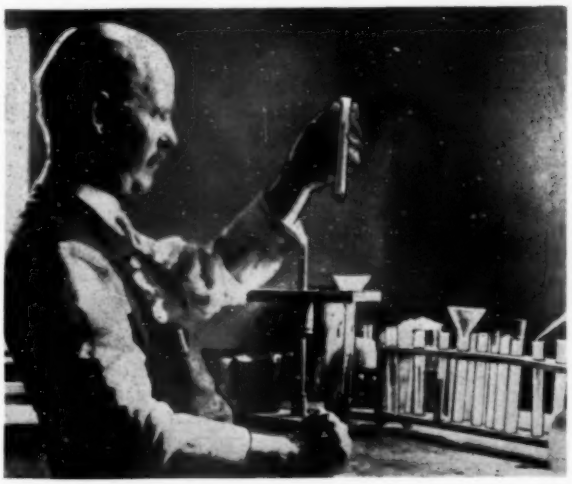
EDWARD GOODRICH ACHESON was born on March 9th, 1856, in Washington, Pa. He was 17 when his father died, and young Acheson was obliged to leave school and take a job as time-keeper at the family foundry, but his enquiring mind was not fully on routine work. He experimented diligently in his spare time, and within a year of his leaving school he had filed his first patent, entitled "Improvements in the Process of Mining Coal, Ore, Clay, etc." (He was, incidentally, granted 70 patents during his life-time.)

He had many jobs during the next few years, ranging from ticket clerk to resident engineer with a railroad company. One of his interests, however, was electricity. While his days were occupied with mainly humdrum duties, his nights were given over to experiments, calculations and theories. At the age of 22 he joined United Pipe Lines as a tank gauger for a salary of 75 dollars a month. By then he had constructed a small dynamo which fascinated him so much that he made up his mind to devote his whole time to electricity. Although U.P.L. offered him a rise of 15 dollars to remain with them, he resigned and sought a position that would give him an opportunity to work with electrical apparatus.

Edison and Light

Thus began a significant period in Acheson's life—the beginning of his association with Thomas Edison, at that time only 33 years old, but already world-famous for his electrical inventions. Determined to obtain the best possible conditions in which to develop his electrical theories, he went to Edison's laboratory and asked the boss for a job. Edison, impressed by his approach, sent him to the superintendent of the machine shop. He was engaged, and during the next few months Acheson, encouraged by Edison's interest in his work, produced an improved version of the dynamo he had previously constructed and abandoned. Subsequently, after a period of preparing the drawings for Edison's patent applications, he was transferred to the research department, where better equipment was at his disposal. There he concentrated on improving the filament for incandescent lamps, and later assumed control of Edison's lamp factory.

In 1880, Acheson won an Edison cash award for producing a graphite loop filament capable of being fitted conveniently into an electric lamp. This led to Edison offering him a contract for the manufacture of 30,000 graphite filaments. Acheson accepted, but the filament dissatisfied him—it gave an excellent light, but had only a short life. Although the contract was a lucrative one, he asked Edison to release him from its obligation. Edison's response was an invitation to learn the lamp business thoroughly by going through every department in his works.



E. G. Acheson in his laboratory.

Widening Horizons—Europe

Acheson made his first trip outside the United States in July 1881, when he sailed for Europe as first assistant to the Edison engineer in charge of his exhibit at the International Electrical Exposition in Paris. One of Acheson's assistants was Nicholas Tesla, who later made a name for himself as the inventor of the "Tesla" induction coil. The exhibition over, Acheson supervised the construction of a lamp factory at Irvy-sur-Seine for Societé Edison Continental, a company formed to operate the Edison patents in Europe. He remained on the Continent for two years, arranging the installation of the first lighting plants in Italy (among the buildings he illuminated was La Scala, Milan), Holland and Belgium, where the main customers were the proprietors of fashionable hotels and restaurants. His salary was then 150 dollars a month.

After a short time with the Edison Italian Company, he left, in indifferent health, for London. He was to return to London many times during the next quarter of a century. Years later, on one such trip, when he had already achieved fame in his own country, he met Will Crookes, the celebrated physicist and pioneer in the X-ray and isotope fields. They became great friends, and Acheson often appeared at Crookes laboratories during his visits to England.

Home—and Financial Success

Back home, Acheson, as he himself wrote, " entered upon perhaps the most important period of my life." This comment doubtless has a double significance, for in that year he married and also set up in business on his own account. On his return to America, he was offered the position of engineer at a new Edison electric power station then being constructed in Lower Manhattan. Acheson, however, declined the offer and severed his connection with Edison. For a time he became superintendent of a competitor's lamp factory in Brooklyn, where he met his future wife. His experiences in Europe, the knowledge he had acquired during his work on electricity, his insatiable curiosity and independent mind, all contributed to his decision to launch out on his own account. Acheson's association with Edison during the development of electrical energy—as novel in the 80's as atomic energy is to-day—had given him a wonderful opportunity to learn a new scientific language, an opportunity he accepted eagerly.

For the next twelve months, Acheson was not particularly successful as an independent inventor, and his financial position became very shaky indeed. He was forced to borrow money from friends to finance his schemes, and by 1885 had acquired a substantial number of creditors. He persevered with his experiments, however, and the following year his efforts were rewarded when he sold a patent for an anti-induction wire to George Westinghouse, acting on behalf of the Standard Underground Cable Company of Pittsburgh. The deal brought Acheson 7,000 dollars in cash, 50,000 dollars of Standard stock and a three year engagement with the Company at 2,000 dollars a year. It also enabled him to pay off his debts, and gave him enough capital to establish later, with the aid of friends, a small electric lighting plant in Monongahela, Pennsylvania. This plant generated electricity for the community at night and provided the power source for Acheson's experiments during the day. It was at Monongahela that Acheson carried out research which led to his interest in the development of abrasives, and to the eventual discovery of silicon carbide.

The Birth of " Carborundum "

At an Exposition held in Philadelphia in 1926, celebrating the 150th anniversary of the signing of the Declaration of Independence, the United States Patent Office exhibited seventeen enlarged reproductions of those patents which they felt had done the most for mankind. Acheson's patent for the preparation of silicon carbide (" Carborundum ") was there ; among the other specifications were those covering the telephone, telegraph and sewing machine.

Dr. Acheson wrote of his discovery thus :—

" An iron bowl, such as plumbers use for holding their melted solder, was attached to one lead from a dynamo and filled with a mixture of clay and powdered coke ; the end of an arc light carbon attached to the other lead was inserted into the mixture. The percentage of coke was high enough to carry a current, and a good strong one was passed through the mixture between the lamp carbon and bowl, until the clay in the centre was melted and heated to a very high temperature. When cold, the mass was examined. It did not fill my expectations, but I, by sheer chance, happened to notice a few bright specks on the end of the arc carbon that had been in the mixture. I placed one on the end of a lead pencil and drew it across a pane of glass. It cut the glass like a diamond. I repeated the experiment, and collected enough of the material to test its abrasive qualities. I mounted an iron disc in a lathe, and, oiling its surface, applied the material which adhered, and with this revolving disc I cut the polished face of the diamond in a finger ring still owned and worn by me."

Acheson called the material " Carborundum," believing it to be composed of carbon and corundum. It was, in fact, as he later discovered, a compound of carbon and silicon (SiC).

The hardness of the " Carborundum " made it particularly useful for gem polishing, where Acheson first attempted to market his product. His limited output was sold to a diamond cutter at the rate of 800 dollars a pound, a transaction which enabled him to buy a microscope and examine the structure of silicon carbide. He then set about the task of interesting emery wheel manufacturers in his product, but they claimed that it could not satisfactorily be turned into abrasive wheels. Acheson did not agree. As a first bold step to proving he was right, he founded The Carborundum Company in 1891. It so happened that the wheels he produced proved to be ideal for grinding the joints of lamps manufactured by Westinghouse, the famous engineer, to whom Acheson had sold his anti-induction wire patent. Working night and day, he made with his own hands 60,000 small wheels, and sold them to Westinghouse for over 7,000 dollars. Acheson, putting the Company's progress first and his own interest last, ploughed back the money and gave The Carborundum Company its own dynamo.

World-Wide Recognition

His sales promotion campaign among 12,000 dentists demonstrated his flair for publicity ; his scheme, carried out in the early 90's, would impress a contemporary publicity man. He sent 12,000 $\frac{1}{2}$ in. diameter " Carborundum " wheels to all the dentists on his " mailing list." The wheels were mounted on cards bearing the greeting : " The Compliments of the Season and a " Carborundum " Wheel. Try me wet or dry " on one side, and a price list on the reverse. The idea was a success ; the sales more than covered the total cost of the scheme.

Demand for " Carborundum " increased. As a result of his exhibit at the Chicago Exposition, Acheson sold the Austria/Hungary patents for 20,000 dollars. He followed up this success by visiting Europe in 1894 and establishing a " Carborundum " production unit in the electric plant at Ivry-sur-Seine, where he had worked 12 years earlier on Edison's behalf. While on the Continent, he sold the patent rights in France, Belgium, Switzerland and Italy for substantial sums. For some reason still unknown, the only country in which " Carborundum " was not patented happened to be England. The following year, Acheson returned to the United States and extended his interests by setting up a 1,000 h.p. plant at Niagara Falls for the manufacture of " Carborundum." In this year, too, Acheson took out a patent which was the first step towards the production of a new and unique industrial lubricant—he patented a method for the manufacture of graphite. It is perhaps a paradox that his name is associated with two products

which are antithetical: "Carborundum," the abrasive; and man-made graphite, the lubricant.

Acheson found that, if finely ground coke were mixed with a pitch binder and shaped into a cylinder or plate under hydraulic pressure, the entire mass could be graphited and machined to any required dimensions. Electrochemists were quick to see the possibilities of graphite (an excellent conductor of electricity) in solid form as electrodes and plates. These products, based on Acheson's electric-furnace graphite, were soon in great demand for use in the manufacture of chlorates, hypochlorates, metallic sodium, caustic soda and chlorine.

The preparation of steels and special alloys by electro-metallurgical processes was greatly facilitated by the use of the strong, inert, highly conductive graphite electrodes. Other applications for Acheson electric-furnace graphite in the electrical field were developed, mention of which is made later in this review.

By 1900, the Acheson Graphite Company had been established at Niagara Falls for the production of electrodes, motor and dynamo brush plates, and other accessories. Patents on graphite manufacture had been taken out in England, France, Belgium, Germany, Austria, Italy, Spain and Russia.

Colloidal Graphite

Between 1903 and 1906 Acheson became interested in the lubricating, rather than electrical properties of graphite. Natural graphite, mined principally in Ceylon, Madagascar and Mexico, was already marketed in powder or flake form for lubrication purposes. The abrasive impurities in the natural product, however, limited its value in industry. Two discoveries led Acheson to the successful colloidalising of graphite. The first was the excellent lubricating properties of some non-coalescing graphite he produced in his electric furnace. The second was his finding a means of producing a substance, which he named Egyptianised clay, and reducing it to such fine particles that they would pass through filter papers and remain indefinitely suspended in water.

Acheson's coinage "Egyptianised clay" derived from the ancient Egyptians use of straw in brick making, a process recorded in the 5th chapter of Exodus. Although he searched the technical literature for some reference to the addition of organic matter to clay during "pugging" or working, the biblical reference was the only mention of this method he could find.

Acheson disagreed with the accepted theory that straw fibre acted as a mechanical binding agent. "Straw," he wrote, "contains no tannin and the effect I had found had always been produced with tannin or a substance containing tannin. I procured some straw, boiled it with water, decanted the reddish-brown liquid and mixed it with clay. The result was like that produced with tannin and equal to the best I had obtained. It now seemed likely that the Egyptians were familiar with the effect I had discovered, and believing this was why they used straw in making bricks and were successful in substituting stubble for straw, I called clay so treated 'Egyptianised' clay."

In these experiments, what Acheson had found was a means of "deflocculating" or colloidalising the clay. He adopted the same method using graphite instead of clay, and described the suspended state of the solid as "deflocculated." The title he coined for his colloidal

Mr. Howard A. Acheson, President of Acheson Industries Inc., looking at the exhibit in the Henry Ford Museum, Dearborn, Michigan, commemorating the centenary of the birth of his father. (With acknowledgment to the Henry Ford Museum).

graphite was "Deflocculated Acheson Graphite," soon reduced to its initial letters "dag" and transformed into a trade mark that still symbolises the products of the organisation that bears his name.

Acheson's first colloidal product, marketed under the name of "Aquadag" in 1907, was a suspension of graphite in water. This was followed one year later by "Oildag" colloidal graphite in oil. Patents and trade marks were filed and registered in 23 countries. To-day, these two products are among more than 50 dispersions of graphite and other solids in various liquids manufactured by the Acheson process at Plymouth, England and Port Huron, Michigan.

Acheson's enterprises flourished. By 1910, 10 million pounds of "Carborundum" were being manufactured in Acheson furnaces every year. The product was then firmly established as an indispensable abrasive in industry.

Honours, Awards and Expansion

Acheson subsequently sold his "Carborundum" interests, but he retained an active association with his graphite plants until his death in 1931. His later years were devoted to the discovery of new outlets for his products, the sale of which had spread to every industrial country in the world. Among the many honours and awards that came to him was the conferment of the honorary degree of Doctor of Science by the University of Pittsburgh.

In 1911 he visited England and founded the British Acheson Oildag Co., Ltd., a title which changed two years later to E. G. Acheson, Ltd.

In 1915 the Acheson Ink Company was incorporated, and the deflocculating process adapted for the production of high quality printing inks. Thus the first step was taken towards the foundation of the dispersed pigments plants which, some years after Dr. Acheson's death, became important affiliated units of the Acheson organisation.

Three years before he died, Dr. Acheson established the Edward Goodrich Acheson Foundation which, under the control of the American Electrochemical Society, awards a cash prize and the Edward Goodrich Acheson Medal to the person who, "in the judgment of the directors of the Society, shall have made such contribution to the advancement of any aspects, purposes and activities fostered or promoted by the Society as to merit such an award." The society unanimously voted Dr. Acheson the first recipient of his own medal for his contributions to electrothermics.

The Significance of Acheson's Products

"Carborundum"

Uses for the hardest abrasive known to science are too numerous to mention in full. It is indispensable in the production of gramophone needles and combined harvesters, razor blades and motor cars. It has revolutionised the working of marble, granite and sandstone. It surfaces and bevels glass, is an essential item in the finishing of fine leather and shoes. Giant "Carborundum" wheels grind wood pulp for the paper industry; pigmy ones shape pearl buttons and precious stones. Its electrical properties give it valuable functions in the radio, television and radar fields. Silicon carbide, manufactured at temperatures between 4,000 and 5,000° F., is heat and corrosion resistant. This is the product that was born in a humble plumber's pot over 60 years ago.

Electric-Furnace Graphite

Tough, inert, highly conductive electrodes made from graphite produced by the Acheson process are valuable in the electrothermic production of calcium carbide, fused quartz, silicon carbide and other abrasives, and the electro-chemical manufacture of sodium, potassium, chlorine, bleaching powder, peroxides, etc.

Electric-furnace graphite is used as brushes for motors and generators, rods for electric cutting and welding, resistors and contacts. It also serves as a moderator in nuclear reactors and played a vital part in the successful development of atomic energy plants in the United States during the second world war.

Colloidal Graphite

The 50 or so dispersions of colloidal graphite marketed under the trade mark "dag" have a thousand and one applications in all branches of industry. Apart from the lubrication of all manner of mechanical equipment, "dag" colloidal graphite is extensively used as a high-temperature and anti-seize lubricant, for the lubrication of dies in the hot working of metals, as conducting coatings in the electrical and electronic industries, as opaques in photo-lithography, and for boiler scale prevention, to mention only a few of the numerous applications for this versatile product.

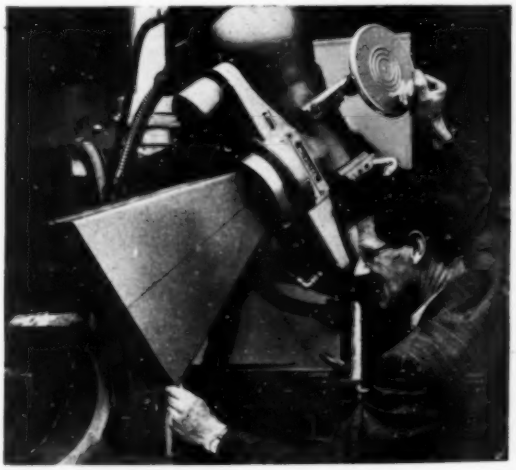
Its uses are legion. The leading engine and car manufacturers find it invaluable as an assembly and running-in lubricant. Most of the cathode ray tubes produced in this country are internally and externally coated with colloidal graphite. Biologists have injected it into the breathing tubes of insects; printers use it to provide contrast on zincos.

Extrusion, forging and wire-drawing dies are extensively lubricated with colloidal graphite. Porous substances, e.g., wood, fabrics and asbestos impregnated with it acquire electrical and lubricating properties. As a parting agent, it can prevent rubber sealing strips from "growing" on metal, or glass from sticking to moulds in bottle-making machines. As one of the thinnest opaque films it has a special value in photo-lithography.

For lubrication at temperatures above the decomposition point of conventional oils and greases, colloidal graphite is ideal: it will lubricate satisfactorily at 600° C. Lubrication of bearings, reduction gears, compressors, steam engines and pumps—there is no end to the list of mechanical equipment on which colloidal graphite is used with great advantage throughout the world.

Industrial X-Ray Orders for Marconi

A CONTRACT for the supply of two 250 kV. industrial X-ray equipments has been awarded to Marconi Instruments, Ltd., by the Ministry of Supply. The units will be installed in the Royal Ordnance Factory at Bishopton, near Glasgow. Each equipment comprises a constant-potential high-tension generator, a control unit, an oil cooler, and an oil-cooled shock-proof tubehead. The voltage range—30–250 kV.—is sufficient for all normal applications and, for example, enables steel of up to 3½ in. in thickness to be penetrated. A special feature of the Marconi apparatus is the constant potential generator, which enables the whole of the high voltage energy to contribute to X-ray generation, ensuring maximum X-ray output and shorter exposure times.



Factory testing of 250 kV. set.

Electrically similar to the above is the Marconi 250 kV. industrial X-ray equipment recently supplied to John Brown (Land Boilers) Ltd., of Clydebank. This equipment is mounted on a two-ton trailer for complete mobility. The control unit is installed in a lead-lined protective compartment, while at the opposite end is the tubehead and tubestand. This apparatus permits the easy radiographic inspection of welds and castings, irrespective of size; it will prove particularly useful in radiography on the two land boilers being built by John Brown (Land Boilers), Ltd., for the South of Scotland Electricity Board. These boilers—believed to be the largest ever to be built in Britain—are for the new power station at Kincardine.

The Fundamental Properties of Metals and Powder Metallurgy

By H. W. Greenwood*

The properties of metals as we know and use them today are largely determined not by the metal itself, but by the impurities and imperfections it may contain. The author refers to the improvement in the properties, particularly ductility, of certain metals as small amounts of impurities are removed, and to the beneficial effects of grain coatings in S.A.P. and in the production of certain alloys in powder form.

IT has been said recently that our views on the dependence of the properties of metals upon the perfection or imperfection of their crystal lattices, and our understanding of how such dislocations or imperfections react, is possibly the most potent factor towards transforming metallurgy, including powder metallurgy, from an art into a science. Whether or not that is an accurate statement, we certainly do know that dislocations and imperfections in the ordered arrangement of atoms can be caused either by a missing atom or by a foreign body, and that the existence of such dislocations can greatly affect the properties of metals and interfere with their adaptability for use for specific purposes.

It is common knowledge that much more is expected of metals and alloys today than ever before, and that we are entering upon an era, which we might call that of atomic energy, in which purity and freedom from physical dislocations and the presence of foreign bodies in the materials used are of the highest importance. This is emphasized by the vision we have had vouchsafed to us of the notable properties with which we could endow our metals and alloys could we only start off with really pure metals and then control the eventual physical properties by the use of alloys providing just those properties that are essential for the particular purpose desired. The possession of such powers of control would solve many problems of both present and future.

Defects in Crystalline Solids

True, our knowledge and experience grow apace, but we are only too well aware of the many phenomena encountered which elude attempts at explanation, or are not covered by the knowledge we at present possess. An outstanding characteristic of science today is its tremendous expansion, so that what, only a few years ago, appeared to be a comparatively simple matter calling for the application of one or two simple physical laws, has now grown to the dimensions of a major enquiry involving half a dozen or more branches of science and calling for the labours of quite a respectable personnel, mostly specialist. Stated somewhat differently, if today we desire to exploit a particular substance, whether metal or non-metal, we find that its chemical composition alone is not sufficient, that we require to know how its lattice is constructed, and the extent to which it possesses structural defects, and what those defects are. It is somewhat disconcerting to find that there are quite a number of these defects, and in most cases the type of defect has been characterized by applying to it the name of its discoverers, or the person who first described it. This may be of historic interest, but it does not disclose just what the defect is. It is comforting to have the opinion of Professor J. Arvid Hedvall about these various lattice defects. He says :[1] "These should be considered as hypothetical models suitable for certain mathematical calculations, rather than as examples of known structures. To obtain a real representation of the nature of various lattice defects by means of still further improved X-ray methods is one of the most important objects of research on solids."

All metallurgists will most fervently agree with Professor Hedvall, not the least those who have had a look at the volume published last year by the Physical Society of London, and bearing the title "Report of the Conference on Defects in Crystalline Solids held at the H. H. Wills Physical Laboratory, University of Bristol, 1954." This is a volume of some 429 pages with 27 plates and comprising some 47 papers. A truly fearsome document, and yet dealing with only one facet of our problem as to the factors really determining the behaviour of metals, whether in powder or solid mass.

Some months ago, we read an editorial statement[2] to the effect that "The properties of the common metals used today take on a very different aspect when the metal approaches purity. For example, the number of dislocations in a metal crystal is a function of the amount of work done and its impurity content." There followed an account of the metal whiskers which have been produced by the Westinghouse Research Laboratories.[3] Here are described single crystals of pure iron having an exactly square cross section and a breaking strength approaching a million pounds per square inch. Said the Director of Westinghouse Research about this product of his laboratories :—"Perfect iron is another forward step in our attempt to gain a broad understanding of the fundamental properties of metals. It is interesting to note that all desirable properties of metals as we know and use them today are actually determined not by the metal itself, but by the impurities and imperfections it may contain."

Effect of Impurities

Some of these pure iron fibres, crystals, whiskers, call them what you will, have been stressed, without plastic deformation, to 110 tons/sq. in. Compare this with a critical stress of 1·78 tons/sq. in. for ordinary iron![2] Less striking examples, but not of less significance in practice, are the many refractory metals formerly

* Powder Metallurgy Ltd., London.

regarded as inherently brittle, but now known to owe their brittle qualities to their impurity content. Titanium and zirconium prepared by reducing the halide with aluminium or magnesium are brittle, and contain up to 0·2 at. % oxygen. When prepared by thermal decomposition of the iodide, the metal rods so produced are very soft and have an oxygen content of 0·01%. Vanadium, long regarded as brittle, is ductile if the oxygen and hydrogen contents are below 0·15 at. %, and can be cold worked after initial hot work.

Ductile chromium has recently been produced from material deposited as electrodes. Tantalum and niobium are brittle when prepared "free from oxygen" by thermal decomposition process, but at 2,500° C. *in vacuo*, sintered bars lose their impurities, and such metals are ductile when cold. Molybdenum also responds to vacuum treatment at high temperatures, losing grainbound oxygen and becoming ductile at room temperature. Molybdenum metal is particularly susceptible to very small amounts of oxygen—as little as a few parts per million by weight: nitrogen has much the same effect on molybdenum as oxygen. A good deal of this information has been known for some time, and to some extent has been made use of generally for some particular object, such as the addition of a few hundredths of a per cent. of sulphur into a melt of alloys of the Permalloy type to produce a cast metal which at room temperature is brittle enough to grind to powder with comparative ease, and so provide a powder that can be used in making cores for use in radio instruments.

There is also the case of the evil effect of the presence of lead, cadmium or tin in zinc which is required for die casting. Another practical use is the addition of a few tenths of a per cent. of carbon to 18–8 stainless steel, followed by heating to a temperature of 500 to 750° C. to produce a coating of the grains with what has been called a sensitized alloy, which, when treated with a sulphuric acid solution of copper sulphate, suffers attack and results in such embrittlement of the alloy that it can easily be powdered. The production of a grain coating to attain new properties has perhaps its most spectacular example in S.A.P. In this case there is a profound effect, amounting to what is almost an entirely new product of aluminium metal plus some 13 to 15% of aluminium oxide, which possesses tensile strength and other physical properties of outstanding quality and value. It has been suggested that one could draw a parallel between the unusual properties of sintered aluminium powder S.A.P. and a Beilby layer, and that it would not be improper to think of S.A.P. as a compact of Beilby layers.[4]

There would appear to be a possibly fruitful field of investigation still open to exploration into the nature and properties, as well as the appearance and origin, of the Beilby layer. It might be of interest to see what would result from attempting its production in a vacuum. Another point of interest lies in the statement that the Beilby layer can only be produced if a metal is polished with another metal having a lower melting point. Also, can it be produced in a hydrogen atmosphere? These are examples of questions that are easy to ask, but to which accurate answers are difficult to find in literature, although correct answers might well be of value, not only in themselves, but because they would open up further possibilities. That might well be said of many other queries which arise in almost any discussion of powder metallurgical procedures. It applies also to many aspects of general metallurgy. So much so that we are compelled to admit that much of our practice, as well as much of our theory, is today more empirical than we would wish. Hence the conclusion is forced upon us that powder metallurgy must be considered as combining art and science, and that there is a very long road to traverse before we can claim that we understand what happens in our handling of material, or that we can prophesy exactly what will happen in any particular set of circumstances.

REFERENCES

1 J. A. Hedvall. Factors Influencing the Reactivity of Solids. Powder Metallurgy, 1954. The Iron & Steel Institute Group I, p. 50.
2 *Metal Treatment*, July, 1955, 275.
3 *Materials & Methods*, July, 1955, 12.
4 Börge Lunn. *Zeit Metallkunde*, 1954, **45**, 92–93.

Titanium's Future

As metallurgists work with titanium, they are able to determine more specifically where its properties will be most useful. According to Harry B. Goodwin of Battelle, titanium is no longer seen as a " wonder metal ", but rather as another very useful structural material with definite but limited uses. In a talk before a recent meeting of the American Institute of Electrical Engineers, Goodwin pointed out the metal's desirable properties and limits and some of the uses for which it appears destined.

Thus titanium's lightness and strength make it desirable for those parts of jet engines and airframes which operate within a certain temperature range. It may have desirable properties for armour. Its corrosion resistance suggests use on shipboard where contact with sea water is necessary. Goodwin suggested that when the metal's cost has been sufficiently reduced, it will be ideal for valves, salt-water piping, deck fittings, etc., as well as for equipment for the chemical industry where titanium's resistance to certain acids and corrosive solutions (particularly chlorides) makes it attractive.

After reviewing the problems which metallurgists have overcome, and still face, in the preparation, handling, and fabrication of titanium, the Battelle metallurgist discussed the future of the metal. He referred to the prediction made by Professor H. H. Kellogg, Chairman of the Office of Defense Mobilization Titanium Advisory Committee, that when the industry is mature, annual production will be of the order of 200,000 tons and the price of mill products is likely to be a little over $2 per pound (in 1954 dollars).

German Contract for Wild Barfield

WILD-BARFIELD gas carburising furnaces have been widely adopted by British car and lorry manufacturers for the production of gears, crown wheels, camshafts and other parts. Now, after thorough investigation and tests on production components, a contract is in hand for one of the leading German car manufacturers. The first deliveries, due shortly, comprise four Wild-Barfield gas carburising furnaces, type GC.2454, operating with Carbodrip, and include the requisite jigs and work baskets to accommodate a multiplicity of automobile components. Certain of the items of control equipment are being supplied from German sources, but the furnaces themselves are British made throughout, and are being delivered as completely assembled units.

NEWS AND ANNOUNCEMENTS

Modern Industrial Analytical Chemistry Congress

A FEATURE of modern analysis that represents almost a revolution in scientific thinking is the continuous supplementation of chemistry by physics. Increasingly, electronic equipment, spectrophotometers, polarographs, fluorimeters and other instruments depending on physical measurements automatically recorded are taking the place of the measurements and manipulations previously made by human operators. From this, it is but a step to extend the design of the analytical instrument to control directly the industrial process, the sample of whose output it is examining.

The Society for Analytical Chemistry, through its Scottish Section, is organising a Congress to be held from June 24th–28th, 1957, at St. Andrews University, at which these new developments in chemical analysis will be discussed and the possible directions of new advances in the future will be reviewed. Among subjects to be discussed are gas chromatography in the petroleum industry, new analytical methods in the electrical industry, the plastic industry, explosives, precious metals, foodstuffs and the pharmaceutical industry. There is to be a section on modern techniques and instrumentation, covering automatic titration and the automatic recording of spectra in relation to industrial problems of analysis. Finally, the Congress aims to review the likely future developments in analytical chemistry, for example, the impact of new instruments, the relationship between official laboratories and chemists in industry, and the possibilities of geochemical prospecting—to name but three. There will also be an exhibition of some of the new types of apparatus.

The organising committee of the Congress consists of DR. MAGNUS PYKE, F.R.S.E., MR. A. F. WILLIAMS, MR. J. BROOKS and MR. H. C. MOIR. The Congress Secretary is MR. J. A. EGGLESTON, Divisional Analyst, Boots Pure Drug Co., Ltd., Airdrie Works, Airdrie, Lanarkshire, Scotland.

1958 European Convention of Chemical Engineering

PREPARATORY work in connection with the European Convention of Chemical Engineering, which is to be held in Frankfurt am Main during the period May 31st–June 8th, 1958, in connection with the ACHEMA 1958 Twelfth Chemical Apparatus and Equipment Congress and Exhibition, has already produced some noteworthy results. The 23 European technical and scientific societies which together form the European Federation of Chemical Engineering will also hold their Second Congress within the framework of the Convention. This Congress will open in Brussels (May 28th–30th, 1958) and will continue in Frankfurt am Main (May 31st–June 8th, 1958). The European Federation of Corrosion, to which some 45 European technical and scientific societies belong, is also planning to hold its Second Congress in Frankfurt am Main. Furthermore, the Gesellschaft Deutscher Chemiker (Society of German Chemists) will hold a Special Meeting, and the DECHEMA, Deutsche Gesellschaft für chemisches Apparatewesen e.V., will hold their 33rd Annual General Meeting during the course of the Convention. Finally, the DECHEMA will conduct an "International ACHEMA Students' Meeting," to which all advanced students of chemistry, physics and engineering as applied to chemical apparatus and equipment and process engineering will be invited. There is also every possibility that meetings and congresses of other technical and scientific societies will be organised and conducted in connection with the Convention.

Fuel Economy Plant Investment

THE Treasury have made the Investment Allowances (Fuel Economy Plant) Order, 1956. Section 15 (3) (b) Finance Act, 1956, provides that investment allowances are to be continued for expenditure incurred after February 17th, 1956, on prescribed fuel-saving plant, if it is installed by way of modification or replacement of plant in use in the United Kingdom. This Order, made under Section 15 (4), prescribes a list of the fuel-saving plant and the conditions, if any, upon which such plant is prescribed. The Order came into operation on August 23rd, 1956, and has been published as Statutory Instruments 1956, No. 1295.

British Oxygen Research Fellowships

BRITISH OXYGEN have announced the award of the following fellowships for post-graduate research. MR. C. M. GEORGE, B.Sc., of Bristol University, for research in the Department of Chemistry, Bristol; and MR. N. G. PARSONAGE, B.A., of New College, Oxford, for research in the Inorganic Chemistry Laboratory, Oxford University. Renewal of fellowships for a third year have been granted to the following: MR. B. F. FIGGINS, B.Sc., at Queen Mary College, University of London; MR. D. H. KIRKWOOD, B.A., in the Department of Metallurgy, University of Cambridge; and MR. R. D. MCCAMMON, B.Sc., at the Clarendon Laboratory, University of Oxford.

Lincoln Electric Company

THE Lincoln Electric Company of Cleveland, Ohio, U.S.A., announce that they have terminated their association with Lincoln Electric Co., Ltd., of Welwyn Garden City, Herts. The sole distributor in the United Kingdom for all their products is now Armco Ltd., 75, Grosvenor Street, London, W.1, to whom enquiries regarding current products and future developments should be addressed.

General Refractories Bursary

GENERAL REFRACTORIES, LTD., have awarded a Post Graduate Bursary for two to three years at Sheffield University to MR. P. G. SMITH, B.Sc. (Tech.) who will, under the direction of PROFESSOR THRING, undertake work on heat transfer and fluid flow in combustion-heated refractory firing kilns.

Beilby Memorial Awards

FROM the interest derived from the invested capital of the Sir George Beilby Memorial Fund, at intervals to be determined by the Administrators representing the Royal Institute of Chemistry, the Society of Chemical Industry and the Institute of Metals, awards are made to British investigators in science to mark appreciation of records of distinguished work. Preference is given to investigations relating to the special interests of Sir George Beilby, including problems connected with fuel economy, chemical engineering and metallurgy. The awards are made, not on the result of any competition, but in recognition of continuous work of exceptional merit bearing evidence of distinct advancement in science and practice.

In general, awards are not applicable to workers of established repute but are granted as an encouragement to younger men who have done original independent work of exceptional merit over a period of years. The Administrators are empowered to make more than one award in a given year if work of sufficient merit by several candidates is brought to their notice. For 1956 two awards were made, each of 150 guineas.

Consideration will be given to the making of an award or awards from the Fund early in 1957. Outstanding work of the nature indicated may be brought to the notice of the Administrators, either by persons who desire to recommend the candidate or by the candidate himself, not later than December 31, 1956 by letter addressed to The Convenor of the Administrators, Sir George Beilby Memorial Fund, The Royal Institute of Chemistry, 30 Russell Square, London, W.C.1.

The letter should be accompanied by nine copies of a short statement on the candidate's career (date of birth, education and experience, degrees and other qualifications, special awards, etc., with dates) and of a list of titles, with references, of papers or other works published by the candidate, independently or jointly. Candidates are also advised to forward one reprint of each published paper of which copies are available.

Smithson Research Fellowship

THE Smithson Research Fund Committee of the Royal Society and the University of Cambridge have awarded the Smithson Research Fellowship to Dr. ANITA I. BAILEY of Newnham College, Cambridge. Dr. Bailey, who is a graduate of the University of Witwatersrand, South Africa, is to carry out an investigation on the surface energy of some solid materials and of the variations in this quantity which may occur when physical conditions are varied, and will work in the Department of Physical Chemistry, Cambridge University.

British Engineers Study Soviet Training

A BRITISH engineering delegation visited the U.S.S.R. last month to study engineering education and training. The nine members of the group, led by Professor E. Giffen, Professor of Civil and Mechanical Engineering at London University, were nominated by the Joint Committee of the Institutions of Civil, Mechanical and Electrical Engineers, and the visit took place under the auspices of the Soviet Relations Committee of the British Council. A return visit to the United Kingdom by a group of Soviet experts is under consideration.

Wickman Banner Lane Extension

ANOTHER stage in the expansion of production resources at the Wickman Banner Lane factory has reached fruition with the completion of a new extension. It provides an additional 24,000 sq. ft. which, together with double-shift working, will substantially expand production of the Company's range of multi-spindle automatics. Commenting during the International Machine Tool Exhibition on the Company's programme of expansion, MR. W. V. HODGSON, Deputy Managing Director, said that this provided convincing evidence of his Company's intention to reduce the delivery period for their products, for which there was a steady and continuing demand, and of which over 40% were being built for oversea markets, compared with the national average of about 25%.

Increased Welding Tuition Charges

BRITISH OXYGEN GASES, LTD., announce that the cost of tuition for all their Oxy-acetylene Welding Courses has been increased from £7 to £10. In spite of the price increase, which has been made to meet increases in the cost of materials used, the courses will still be run at a loss. The price of the Oxy-acetylene Cutting Course remains unchanged at 15s. per day, and the cost of the Argonarc Welding Course also remains unchanged at £11 5s.

Symposium on Microchemistry 1958

IT is proposed to hold a Symposium on Microchemistry in 1958 under the auspices of the Society for Analytical Chemistry organised by the Midlands Section and the Microchemistry Group. The Symposium will be held in Birmingham over the period August 20th–27th (inclusive). Further details will be announced at a later date.

Large Order for Birlec

FOR producing diesel crawler tractors Caterpillar Tractor Co., Ltd., are building a new factory at Tannochside near Glasgow. In connection with the scheme, Birlec, Ltd., have been commissioned to build three roller hearth furnaces. The order consists of a 400 kW. furnace for hardening forgings at the rate of 2,000 to 2,500 lb. per hour; a 320 kW. double-ended furnace for tempering rough and machined parts previously hardened in the 400 kW. furnace; and a 475 kW. continuous driven furnace with cooling and soaking sections for cycle annealing 2,000 lb. of components per hour

B.T.H. 330 kV. Switchgear for Kariba

THE British Thomson-Houston Export Company have been awarded the contract, valued at over £2,000,000, for the whole of the 330-kV, switchgear for the Kariba Hydro-Electric Scheme of the Federal Hydro-Electric Board, Federation of Rhodesia and Nyasaland, with Merz and McLellan as consultants. The order covers six complete 330-kV substations located at Kariba, Kitwe, Norton, Sherwood, Salisbury and Bulawayo, incorporating twenty-three oil circuit-breakers. The order is one of the largest switchgear contracts ever secured by a British firm, and is among the first orders placed in Britain for 330-kV switchgear. The 330,000-

volt circuit-breakers included in the contract are a direct development of those installed by B.T.H. on the British 275-kV Super Grid, and are of the bulk oil type, having lenticular tanks and including six breaks per phase, shunted by switching resistors.

Arctic Hydroelectric Plant

Two 50-MVA. 428-r.p.m. vertical waterwheel generators have been ordered from Metropolitan-Vickers Electrical Co., Ltd., by Norges Vassdrags Og Elektrisitetsvesen for extensions at Rossaga, a power station on the fringe of the Arctic Circle. These generators will supply power to an iron works and an aluminium works near the power station. The high electricity consumption in Norway is mainly due to the enormous amount of power required for aluminium production, and it is almost all obtained from hydroelectric schemes such as Rossaga.

Personal News

MR. C. N. KINGTON, M.B.E., has resigned his post as Group Manager of the British Iron and Steel Research Association's Sheffield Laboratories, Director of Research of the Cutlery Research Council, and Research Superintendent of the File Research Council, in order to become Chief Mechanical and Electrical Engineer of Messrs. Husband & Co., Consulting Engineers and Architects, who have offices in Sheffield, London and Ceylon.

DR. J. PEARSON, Assistant Director of the British Iron and Steel Research Association, has, from September 1st, taken over control of the Sheffield Laboratories, and has his office at Hoyle Street, Sheffield, 3. He retains the the Headship of the Steelmaking Division, but has relinquished control of the Chemistry Department, for which Mr. E. W. VOICE, Head of the Ironmaking Division is now responsible. MR. R. MAYORCAS has been appointed Deputy Head of the Steelmaking Division. MR. J. G. WISTREICH, who has been Head of the Metal Working Laboratory at Hoyle Street, becomes Head of the Mechanical Working Division, as MR. W. C. F. HESSENBERG, Deputy Director of BISRA, has relinquished control of the Division in order to devote the whole of his time to his other duties. MR. S. S. CARLISLE, Head of the BISRA South Wales Laboratories, has been appointed Deputy Head of the Division.

MR. E. A. OLDFIELD, has been appointed Senior Research Officer of the Cutlery Research Council in succession to MR. C. N. KINGTON.

DR. J. PEARSON has been appointed consultant to the File Research Council. MR. R. H. HANCOCK continues as Senior Investigator.

MR. R. N. HARLE, Manager of Mufulira Copper Mines, Ltd., has been appointed Assistant Consulting Mining Engineer of the following companies in the Rhodesian Selection Trust Group: Mufulira Copper Mines, Ltd., Roan Antelope Copper Mines, Ltd., Chibuluma Mines, Ltd., R.S.T. Services, Ltd., and R.S.T. Exploration, Ltd. He will take up his new duties on January 1st, 1957, at Kalulushi, where the Group's Consulting Mining Engineer, MR. J. P. NORRIE, is also based.

BRITISH INSULATED CALLENDER'S CONSTRUCTION CO., LTD., announce that MR. C. O. BOYSE, has resigned from the Board and General Managership of the Company on his appointment to the Management of the Automatic Telephone and Electric Co., Ltd., and that MR. O. J. CROMPTON, and MR. G. H. WALTON have been appointed Joint General Managers as from September 1st, 1956.

MR. MARCUS LANGLEY has resigned as Managing Director of Tiltman Langley, Ltd., owing to ill health. He will remain a Director of the Company and will resume his activities as soon as his health permits. MR. A. HASSELL TILTMAN has been appointed President of the Company and MAJOR H. H. SYKES has been appointed Acting Managing Director, pending the appointment of a successor to MR. LANGLEY. MR. L. A. WINGFIELD, M.C., D.F.C., has been appointed Chairman following the resignation of MR. W. R. TOMKINSON, who became Temporary Chairman last November.

MR. G. C. ORAM, Manager of the Central Engineering Workshops at Appleby-Frodingham Steel Company, Scunthorpe, has been additionally appointed Technical Consultant (Engineering Works) to the United Steel Cos., Ltd.

MR. E. E. JONES, Group Commercial Director of the Solartron Electronic Group, Ltd., is at present on a six-weeks sales tour of North America, in the course of which he expects to cover 14,000 miles.

THE WOLVERHAMPTON METAL CO., LTD., has announced the appointment of MR. A. GILLOTT as Secretary in succession to MR. R. M. PARKER. MR. R. J. HUGHES becomes Deputy Secretary.

LORD REITH has been appointed a Director of the British Oxygen Co., Ltd.

MR. R. WILSON has been appointed Divisional Managing Director of British Electro Metallurgical Company, Wincobank, Sheffield.

MR. E. WEST and MR. B. MORRISON have been appointed Directors of Norton Grinding Wheel Co., Ltd. Mr. West is the firm's Chief Accountant and Mr. Morrison, General Works Manager.

MR. R. MCKINNON WOOD has been appointed Vice-Chairman of the Committee, under the Chairmanship of Professor Willis Jackson, which will advise the Government on the Recruiting and Training of Technical College Teachers. Mr McKinnon Wood is chairman of Griffin & George, Ltd.,

MR. E. S. WADDINGTON, of the Industrial Division of Philips Electrical, Ltd., has again been elected Vice-Chairman of the Finance Committee of the Institute of Welding.

Obituary

WE regret to record the death of the following:

BRIGADIER-GENERAL WADE H. HAYES, O.B.E., who died at Chappaqua, a village in New York State, after a sudden and brief illness. Brig-Gen. Hayes, who was on a visit from London to his family in the United States, was Chairman of Edmundsons Electricity Co., Ltd., and a Director of the English Electric Co., Ltd., D. Napier & Sons, Ltd., and Marconi's Wireless Telegraph Co., Ltd., He was 77 years of age.

DR. A. E. J. VICKERS, who died suddenly on Saturday, September 8th, 1956, became Director of Research to The Thermal Syndicate, Ltd., in November 1947, and was appointed to the Board of Directors in April 1953.

RECENT DEVELOPMENTS
MATERIALS : PROCESSES : EQUIPMENT

Dual Portable Power Point

So that two portable electric tools or other electrical appliances can be operated simultaneously and at a distance from a convenient source of power, a Wolf portable power point has been made available. The unit consists of a drum mounted on a stand and a pair of built-in 13 amp., 3-pin, ring main, insulated and shuttered flush sockets. These are connected to a terminal block mounted in the centre of the drum. The cable drum is capable of accommodating 100 yards of 23/0·0076 in., 90 yards of 40/0·0076 in. or 60 yards of 70/0·0076, 3-core T.R.S. cable.

Paying out cable from the Wolf portable power point.

The portable power point overcomes the problems of awkward job locations and remote supply points. For factory or outdoor use, it provides complete flexibility in power tool application, and should prove invaluable to maintenance engineers, builders, electrical contractors and all engaged on repair and installation work. The nett weight is 9¾ lb., the height 12 in., the depth 10¼ in. and the length 14½ in.

Wolf Electric Tools, Ltd., Pioneer Works, Hanger Lane, London, W.5.

Metal Rectifier Welding Set

A NEW metal rectifier welding set—MCR 375—has been added to their existing range by Quasi-Arc, Ltd., It comprises a transformer, regulator and selenium plate rectifier, is specially designed for single operator welding duty with rods from 16 s.w.g. to ¼ in., and is constructed to B.S. 171 : 1936 and B.S. 638 : 1954, where applicable. Insulation is class A. The equipment is intended for operation from a three-phase, 50 cycle supply having an input voltage range of 360/440. The welding current control is stepless and covers the range 30/375 amps. D.C., the maximum welding current being 375 amps. D.C. at 35 arc volts at a duty cycle of 50%. Maximum continuous current is 250 amps. D.C. Open circuit voltage is 64 volts D.C.

Rectification is by a three-phase bridge-connected selenium metal plate rectifier, giving a stable arc with high electrical efficiency and high power factor (0·8 at maximum output) together with a balanced mains loading. Static and silent, these rectifiers have a long life and require little maintenance. The step-down transformer is double wound, and an inbuilt three-phase contactor is connected in the supply to the primary winding. Stepless control of the output over the whole range 30-375 amps. is made possible by a three-phase moving core.

An H.F. filter circuit can be fitted when the equipment is intended for use with an H.F. unit. The components are cooled by a fan incorporating a centrifugal switch which prevents the equipment being used if the fan is not working. The air flow is directed downwards, which lessens the internal accumulation of dust.

The equipment is mounted in a robust angle iron frame, while the housing is a rigid, easily detachable sheet steel case in the form of two wrap-round pressings and a top cover having generous louvres.

The control panel is recessed and thus protected from damage or accidental operation. Start and stop buttons are fitted, and an indicator lamp shows when the equipment is energised. A D.C. ammeter and a voltmeter are also incorporated when specified.

The set is provided with a centrally mounted lifting eye, and the whole equipment is supported on floor skids. A manually towed and steerable four-wheeled undergear is available if required.

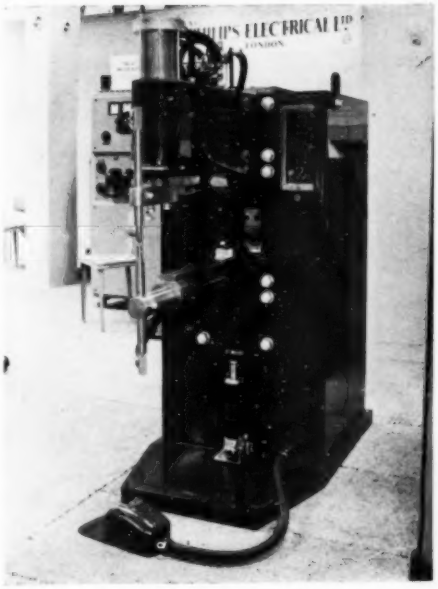
Quasi-Arc, Ltd., Bilston, Staffs.

Spot/Repeat Welders

A NEW 40 kVA. air-operated single and repeat spot welder, the first of a completely redesigned series comprising 40, 60, 100 and 150 kVA. welders, has been introduced by Philips Electrical, Ltd.

A feature of the series will be its versatility; based on a standardised frame, the major components such as pressure cylinder and lower arm arrangements will be interchangeable.

The 40 kVA. welder, has a throat depth of 12–36 in. and, like all the series, is fitted with a four-function timer controlling squeeze delay, weld-, hold- and off-time. This can be quickly removed as a complete unit for servicing, and is fitted with a lock to prevent unauthorised adjustment once a sequence has been set. Primary current control is by an ignitron contactor. The lower arm arrangement allows for versatile entry of components and can be raised or lowered by means



The Philips 40 kVA spot/repeat welder.

of a hydraulic jack. The foot switch incorporates two pressures—the first to close the electrodes and the second to initiate welds. This feature should be particularly appreciated when spot welding in difficult positions. Restrictors are fitted to cushion the downward thrust in order to prevent hammering. When used for repeat welding, speeds of up to 180 spots per minute are possible.

Philips Electrical, Ltd., Century House, Shaftesbury Avenue, London, W.C.2

Welding and Cutting Blowpipes

THE British Oxygen Company has recently introduced a completely new range of oxy/acetylene hand welding and cutting blowpipes, marketed under the name Saffire, and available in three basic forms—a universal cutter, a welding blowpipe, and a combined welding and cutting outfit.

The universal cutter sets a new standard in safety and efficiency for gas cutting blowpipes. The design embodies the nozzle mixing principle, which greatly reduces the chance of backfire, thereby increasing the safety factor. It will cut steel up to 12 in. thick and cast iron up to 3 in. thick, and it is available with heads of varying angles (90°, 75° and 180°). A Saffire heavy cutter with 75° angle head is also available for cutting thicknesses of mild steel from 12 to 20 in., and cast iron up to 18 in. thick.

The basic Saffire welding blowpipe consists of a shank and mixer, together with a wide range of newly-developed swaged copper tips for all classes of welding. Alternatively, the shank and mixer is available with long and short bent necks, to which conventional detachable nozzles may be fitted in a wide range of sizes.

The combined outfit is supplied with all the necessary fittings to enable the equipment to be used either as a cutter or welding blowpipe, and is available in a stout carrying case, if required. It is available in three basic types—as a general engineers' set, motor engineers' set and agricultural set. The nozzles and extensions can, however, be ordered to suit a customer's particular preference.

An unique feature of the Saffire range of equipment is that once the customer has a shank and mixer, he can purchase any of a wide range of nozzles, as necessary, and even convert his welding blowpipe into a hand cutter, if required. Also available are attachments for other uses, such as flame cleaning, and heating.

The British Oxygen Co., Ltd., Bridgewater House, Cleveland Row, St. James's, London, S.W.1.

Thixotropic Paint

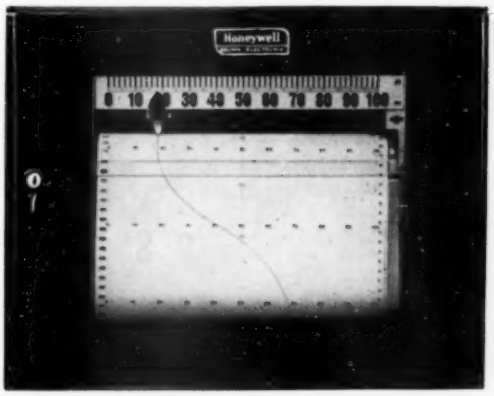
ALLWEATHER PAINTS LTD. announce their Pitan Thixotropic Paint, which provides important advantages in paint application. In consistency, it resembles ordinary jelly, and this thixotropic condition is responsible for its remarkable properties. It is held in exactly the same condition from the day it is made, and is ready for use the moment the lid is removed. No stirring is necessary, and there is no fear of colour variation during use. It is available in sixteen colours, in addition to black and white, and can be supplied in gloss or flat finish.

Painting with thixotropic paint is pleasant and quick; a substantial quantity of paint is picked up by the brush, and a large area is covered each time. The action of brushing causes the paint to flow, and it spreads smoothly and evenly without leaving brush marks. There is little or no chance of runs or wrinkles forming. Stirring or undue agitation in the tins turns Pitan Thixotropic Paint to liquid, but it reverts to its semi-solid state on standing. During normal use, it will not spill if the tin is knocked over, nor will it drip off the brush. This material will appeal particularly to those responsible for painting with a works fully operational.

Allweather Paints Ltd., 36, Gt. Queen Street, London, W.C.2.

High Speed Strip Chart Recorder

A STRIP chart potentiometer recorder with a pen speed of ¼ second (full scale travel) has recently been introduced by Honeywell-Brown, Ltd. The electronic null-balance



The Electronik high speed strip chart recorder

servo measuring system incorporates a newly designed "plug in" amplifier with a high input impedance and output power. The latter is approximately eight times that of the amplifier used in conventional Electronik recorders. The amplifier output drives a new type of balancing motor having a no-load speed of 1,650 r.p.m. The design refinements of the motor, amplifier and slidewire assembly produce a pen speed giving full 11-in. scale travel in only ¼ second. A tachometer circuit provides damping which is strictly a function of pen speed, and is adjustable by means of a rheostat.

The ¼ second recorder is designed to meet the demands of scientists and development engineers who need to record rapidly changing variables. Typical applications are found in guided missile development, where rocket and rocket fuel performance are studied; the determination of instantaneous rates of flow, as met in jet engine development; analogue computer output recording and spectrographic analysis, where high scanning rates and small changes are common.

Full details of the ¼ second recorder are provided on Instrumentation Data Sheet No. 10.0–21.

Honeywell-Brown, Ltd., 1, Wadsworth Road, Perivale, Middlesex.

"Bremsstrahlung" Thickness Gauge

THE beta gauge nowadays is an accepted method of measuring the thickness of strip and sheet metal, having, as it does, so many advantages over other means of gauging which have been used in the past. Unfortunately, until now, it has not been possible to gauge all thicknesses of metal which are rolled, since with beta-emitting radioactive sources, the top limit has been about 0·020 in. in steel, and, of course, equivalent thicknesses in other metals. Above this thickness there was a considerable gap before gamma-emitting sources could satisfactorily be employed. This gap was roughly from 0·020 to 0·250 in. in steel, which, as will be realised, is an extremely important thickness range for many rolling mills.

By making use of a beta-emitting radioactive source and applying it in a novel manner, a nucleonic gauge utilizing the resultant 'Bremsstrahlung' radiation has been evolved. What this means to the metal-roller, in simple terms, is that the "gap has been closed"! The new gauge successfully measures the thickness range 0·020–0·250 in. and can, in fact, be so arranged as to measure even lighter gauge material. Consequently it is now possible by means of the three types of Baldwin Gauges, Beta, Bremsstrahlung and Gamma, to measure form 0·0005 in. to several inches of steel.

Baldwin Instrument Co., Ltd., Brooklands Works, Dartford, Kent.

Sigma Spot Welding

THE latest addition to the range of Quasi-Arc Sigma equipment is the spot welder, which combines the reliability of the Sigma process with the high production speed of spot welding. Mild steel, stainless steel and copper-base alloys can be spot or plug welded up to ¼in. thickness, and, as the weld area is shielded by inert gas, the weld is free from oxide inclusions and has a smooth and clean surface.

Once the controls are set for the required conditions

The Sigma spot welder in operation.

the process is automatically controlled. The operator merely positions the torch over the joint, presses the trigger, and in two to five seconds the weld is complete and the torch is ready for the next weld.

Welding is from one side only, thus avoiding difficulties where access from both sides is impossible, and no forging pressure is required. Filler wire is automatically fed into the weld pool and controlled so that the 'sink holes', which are common with other spot welding methods, are eliminated.

High production rates of up to 20 spot welds per minute, (including positioning and post-weld shielding), and high quality welds with minimum finishing keep costs down and make the process very economical. In addition, the Sigma spot welder can be converted in a matter of seconds from spot to seam welding, making it a very flexible and useful piece of equipment for any fabrication shop.

Quasi-Arc, Ltd., Bilston.

New Range of Industrial Drills

PRODUCTION has commenced on a new range of industrial portable electric drills which incorporate fully insulated pistol grip handles and motors of advanced design, and which are claimed to be the safest and most powerful machines of their type available. Manufactured by Wolf Electric Tools, Ltd., the drills (which range from ¼ to ½ in. capacity) are an extension of the existing well known WD range of ½ to ¾ in. heavy duty industrial drills. The type numbers of the new machines are: WD2c ¼ in. capacity heavy duty drill, WD23c $\frac{5}{16}$ in. capacity heavy duty drill, WD3c ⅜ in. capacity heavy duty drill, and WD34c ½ in. capacity low-speed drill. Performances of these new portable electric drills, expressed in in./min. penetration and translated into production drilling time, represents an average saving of 5¾ hours in every ten taken by earlier and other makes of portable electric drills.

Wolf Electric Tools, Ltd., Pioneer Works, Hanger Lane, London, W.5.

CURRENT LITERATURE

Book Notice

ELECTRIC MELTING AND SMELTING PRACTICE

By A. G. E. Robiette, M.Sc., F.I.M. Roy. 8vo, 347 pp., 121 illustrations. Published by Charles Griffin & Co., Ltd., 42, Drury Lane, London, W.C.2. Price 50s., postage 1s. 3d.

It is about twenty years since the author published his first book on "Electric Melting Practice," during this time great progress has been made in furnace technology, particularly with regard to electric melting and in the control of melting conditions. In addition, however, electric smelting has assumed increasing importance in many countries, and there has been considerable advancement in smelting techniques. With the development in construction and methods of application of electric furnaces to incorporate the increasing knowledge of metallurgical processes, there has been a growing need for a reliable book on the subject in view of the great strides made. This is adequately met by this completely new book by Dr. Robiette.

Metallurgically, the electric method of heating has many advantages: it provides heat very quickly and at will, and gives a very high temperature; the heat may be regulated, which permits a charge to be brought to any temperature desired, and to be maintained steadily at that temperature; it is the cleanest of heating agents and exerts no harmful effect upon the material heated by the evolution of gases; it permits treatment of the metal under oxidising, reducing or neutral slags, in the case of ferrous materials; and, because conditions can be controlled to avoid elimination of alloying elements from the metal, it permits close control of the composition of the metal. It is not surprising, therefore, that the application of electric heat has greatly increased, especially in recent years.

This book deals exhaustively with the construction and operation of the principal types of electric furnaces that are favoured in Great Britain and abroad, and discusses many new processes and techniques. The basic principles of operation and the electro-chemistry of the different processes are clearly explained. Special attention is given to changes in design of plant due to increasing size and mechanisation. The arc furnace, which is by far the most important melting appliance using electric heat, is considered in the first three main chapters, one being concerned with the direct arc types mainly used for steelmaking, the second with indirect types now almost entirely used for the melting of cast irons and non-ferrous metals, the latter being discussed in a separate chapter. Some 130 pages on the many aspects of the arc furnace indicate the important part played by this type of equipment.

The next two chapters are concerned with induction furnaces, one being devoted to the normal-frequency or channel type, and the other to the high-frequency or coreless type. In the former, the experiments that led to the development of the Ajax-Wyatt furnace are discussed, together with a number of other furnaces, similar in principle, some of which were designed for aluminium melting. The coreless induction furnace has been put to various uses during the last 25 years, but its widest scope is in the production of high-grade carbon and alloy steels, principally tool steels, and other complex ferrous alloys previously melted in the crucible; it is now firmly established in metallurgical melting practice. Theoretical aspects and the practical working operations of these types of furnaces are admirably presented.

A chapter of 21 pages is devoted to various types of resistor furnace, embodying external resistor elements transferring their heat to the charge mainly by convection and radiation, several of which are described. Particular reference is made to the rocking resistor furnace, in which the resistor is a graphite rod, and to many types employing metallic resistor elements, which are used for melting metals and alloys of low melting point.

The remaining three chapters deal with electric smelting, and are concerned with pig-iron, ferro-alloys, and non-ferrous metals. Although the modern blast furnace is one of the most efficient metallurgical appliances, coking coal does not exist in many parts of the world, and the cost of importing it has increased greatly since the war. With the large increase in electrical generating capacity, the application of electric heat for smelting has developed. The size and number of electric pig-iron installations, for instance, are increasing year by year, and their output represents a considerable tonnage. Economic considerations are discussed, as is plant development and the design and operation of several plants producing pig-iron. Electric smelting has been used for many years for the production of high-grade ferro-silicon, ferro-chromium, silico-manganese, and several other ferro-alloys, and furnaces for these various purposes, together with their operation, are discussed in considerable detail. In the final chapter, attention is directed to the increasing use of the electric furnace for the processing of non-ferrous minerals, particularly the smelting of tin, zinc, and oxidised nickel ores, and the melting of sulphide concentrates and ores of both copper and nickel for the production of matte, which is subsequently blown in a converter. The processes, together with the plant employed, are discussed in a practical manner.

This excellent book, which includes nine pages of bibliography and an adequate index, has been written by one having considerable practical experience, coupled with exceptional opportunities for the study of existing installations, and there is no hesitation in stating that it will be regarded as a standard work on the subject for many years to come.

Trade Publications

The instrumentation of open hearth furnaces is a well established practice, but automatic control is still in its early application stages. The majority of furnaces are still manually regulated by the melters, although many shops have now installed panels on which all instruments are grouped together. Publication TP 5006/456, recently issued by George Kent, Ltd., describes examples of

automatic control schemes applied to open hearth furnaces in this country and abroad. The examples have been selected to illustrate the alternative schemes of automatic control for different fuels used in the steel industry, including raw hot producer gas, and dual fuels such as blast furnace and coke oven gas, oil and coke oven gas, and oil and natural gas.

BULLETIN No. 161 of *Aero Research Technical Notes* presents a paper by C. Mylonas, Professor of Engineering, Brown University, Rhode Island, U.S.A., on "Experiments on Composite Nodules with Applications to Cemented Joints," in which the author uses the photoelastic method of studying the stress distribution.

DURING the past 25 years there has been a rapidly growing appreciation of the value of industrial radiography, which had led to an increased demand for trained radiographers. The Kodak School of Industrial and Engineering Radiography provides this training, and a booklet recently issued by Kodak, Ltd., sets out the various courses available at the school. The general course, officially recognised as the Lloyd's Approved Course in Casting and Weld Radiography, lasts 4 weeks; the Lloyd's Approved Course in Shipbuilding Radiography lasts 3 weeks; the Surveyors and Engineers Course in Radiography lasts 2 weeks; and the Course in Gamma-Radiography lasts 1 week.

FOR issue to Youth Employment Officers and those concerned at schools, technical colleges and universities with advising young people on careers, English Steel Corporation, Ltd., have recently produced a new brochure describing facilities available for further education and training within the E.S.C. Group of Companies. In a foreword, the Managing Director, Mr. W. D. Pugh, points out that, as the Company's policy has always been to promote from within, wherever possible, recruitment has to be carefully planned to include people with every type of education and background, and training schemes must be comprehensive and flexible enough to allow anyone with real ability to rise to the top, no matter where he or she begins.

THE Spring 1956 issue of *European Bulletin of Zinc Alloy Die Casting*, obtainable from the Zinc Development Association, 34 Berkeley Square, London, W.1, is devoted to the European toy industry and the part played by die castings in toy manufacture. It is extensively illustrated by pictures of toys and toy components made in the form of die castings in Great Britain, France, Germany, Holland, Italy and Switzerland.

THE first article in the Summer 1956 issue of *Torch*, the British Oxygen quarterly technical bulletin, features the M.S. *Bergensfjord*, the first all-welded passenger liner with an all-welded aluminium superstructure. Other articles deal with such topics as the welding of titanium and Argonarc spot welding of coachwork for Rolls Royce and Bentley cars.

THE versatility of the Araldite epoxy-resins is emphasized in Bulletin No. 163 of *Aero Research Technical Notes*, which features an article entitled "Araldite in Many Enterprises." The first application described is in the field of pottery, where Araldite Casting Resin M is used in the production of cases for making cup moulds. Then follow two shipbuilding uses: the first concerns the application of Araldite 121N to the eroded area of the rudder of the *Queen Elizabeth*; the other refers to the use of Araldite D in conjunction with Tyglas fine glass net bandage for the corrosion protection of high tensile steel propeller shafts. The remainder of the article describes the use of Araldite 102 in the sectioning of the Dead Sea scrolls, and the construction of marble relief maps in which the layers are glued with Araldite 900.

THE August-September issue of *The Bonderizer*, published by the Metal Finishing Division of The Pyrene Company, deals with three users of Pyrene metal finishing processes —The Austin Motor Co., Ltd., Creed & Co., Ltd., and Dewrance & Co., Ltd. The first named has been a user of these processes since November 1930 and now has six Parkerizing plants, two Parco-Lubrizing plants, a Pyluminizing plant, and a large fully-automatic Rotodip Bonderizing plant for body shells. Creed & Co., Ltd., use Bonderizing and Pyluminizing in the manufacture of equipment for facsimile transmission of documents. Spindles and spring blocks for Dewrance valves are Parkerized to protect them against rust and corrosion.

NOW that the aluminium-silicon-copper-zinc casting alloy designated ALAR 21 has been incorporated in B.S.1490—Aluminium Alloy Ingots and Castings for General Engineering Purposes, ALAR, Ltd., have issued a revised individual data sheet for LM-21 Aluminium Casting Alloy. This deals with chemical composition, mechanical properties, strength at elevated temperatures, physical properties, machinability, corrosion resistance, anodising, casting characteristics, heat treatment, and applications.

THE Switchgear Department of The English Electric Company has issued a new publication (SG/333) describing its type OB2 switchgear for use up to 600 amps working at 660 volts A.C. or D.C. This robust compact circuit-breaker is used extensively for applications where repeated operations and limited maintenance are required, such as direct-on starting of motors in factories and power stations. There is also a growing demand for colliery use, in connection with surface plant, where the compact dimensions offered by OB2 switchboards of double-tier construction are ideal.

TO meet the need for a concise but reasonably complete introduction to the problems associated with the use of aluminium overhead transmission conductors, Aluminium Union, Ltd., have recently produced a new handbook, which they believe will have considerable value both to students and to engineers engaged in this branch of electrical engineering. Amply illustrated, the booklet contains sufficient detail of the necessary methods of calculation and also easy reference tables and charts to enable an engineer to carry out normal straightforward line design problems without further reference. This publication is intended for world-wide distribution, but a domestic version is available for U.K. readers from the associated company, Northern Aluminium Co., Ltd., Banbury.

WE have recently received from George Kent, Ltd., Publications 970 and TP 5009/856. The former is a spare-parts list for sampling systems for oxygen analysis, and the latter a reprint from *Process Control and Automation* of an article on "Control of a Sulphur-Recovery Plant." The purpose of the plant is to extract sulphur from hydrogen sulphide gas produced in the manufacture of carbon disulphide. A feature of the plant is a large instrumentation and control panel installed by George Kent, Ltd.

LABORATORY METHODS
MECHANICAL · CHEMICAL · PHYSICAL · METALLOGRAPHIC
INSTRUMENTS AND MATERIALS
OCTOBER, 1956 Vol. LIV, No. 324

Particle Size Determination in Powder Metallurgy

A General Review of Available Methods

By L. A. Phelps, A.C.T. (Birm.)

To the powder metallurgist, a knowledge of the size range of his raw material, and of its distribution within that range, is important, as the properties of the powder are greatly influenced thereby. The basic principles underlying the more important methods for obtaining this information are briefly discussed.

SINCE powders of uniform particle size are rarely encountered in powder metallurgical practice, it is necessary to determine the particle size distribution: that is, the quantitative distribution of the particles among the various sizes, which can be represented by plotting either the weight percentage or the number of particles against the particle size.

The particle size is given as a diameter for spherical particles and as an average diameter for non-spherical particles, although the latter is not a unique length which can be measured directly. Particle size, therefore, is not a concise quantity, but, for any given non-spherical particle, may have several values with different meanings, depending on the sizing method used.

In the microscopic method, size is measured as an average of several dimensions ; in sieving, it is measured as the aperture of a square mesh sieve of standard weave, which will just retain the particle ; in sedimentation it is measured as the diameter of a sphere of the same specific gravity and the same settling velocity ; and when the determination involves fractionation, the average particle volume of the fraction can be determined by counting and weighing, and the average particle diameter can be given as the cube root of the volume.

The particle sizes encountered in the powder metallurgical field vary between 1,700 and 0·1μ (1·7–0·0001 mm.). For particles of not less than 50μ, sieving is usually used ; below this size there are several methods employed, each with its own advantages and disadvantages. Particle size distribution analysis can be divided into two main sections, namely :

(1) Sieve size analysis, for particles over 50μ.

(2) Sub-sieve size analysis.

Various methods may be used to determine the distribution in each case, and in some cases the whole range of particle size distribution for a given powder can be determined.

Sieving Methods

Sieving methods can be carried out by hand, but are best done in a mechanical shaker, one of the most widely used being the Rotap. The sieves are clamped in a specially designed frame and are given a rotary motion and a periodic tap by a lever mechanism to distribute the powder over the screen. The screens used are standardised as to their aperture size, method of weaving the wire, and wire diameter. There are two standards, namely the British Standard Sieve Number and the American Tyler Sieve Standard.

The Tyler Standard is used fairly extensively for work in the powder metallurgy field, since the Americans were the first to commence standardisation. It has as a standard the 200-mesh sieve of aperture 74 μ, all other sieves being calculated by multiplying or dividing by multiples of $\sqrt{2}$. Usually, 400μ is the practical upper limit for sizing sieves.

When conducting a sieve analysis, a sample of known weight is taken, usually 100 g., and is sieved for 15–20 mins. When this is completed, the weight of powder resting on each sieve is measured and the analysis written down as, e.g., $-100 + 120$ mesh, giving the sieve through which the powder passed and the sieve on which it is retained.

Sieving methods are quite satisfactory until problems of shape of particle, the absolute number of particles in a given size range, or the surface area, are related to the percentages by weight ; it is then possible to get three different distribution curves. The problem of particle shape affects any method of determining particle sizes unless the particles are spherical, sieving methods sorting by effective minimum diameter, the microscope giving true sizes, sedimentation methods giving average sizes, and absorption methods giving surface area.

Microscopic Methods

The difficulty here lies in obtaining a true representative sample of the powder ; once this has been obtained the method is fairly simple, though rather laborious. One method of working is to draw a line across the projected image of a particle, so that each side of the line has the same area. Such measurements are called "Martin Diameters," and it is usual to take several measurements of the same particle and average these results. A shape factor is sometimes quoted, this being the ratio of maximum length to minimum width. A major snag after obtaining a representative sample is the natural tendency for particles to settle with their flattest size in the field of view.

For routine checking of particle sizes with the microscope, it is usual to count the number of particles in a given field which are within a known size range. A card with a series of holes of known size can be used in

conjunction with a photomicrograph, by placing the card over the photograph and marking each particle just larger than or just smaller than one of the holes in the card. Alternatively, the image may be projected on to a screen and the number of particles of a given size counted.

Where the microscope is used for size determination, it is usual to say that the number of particles counted has a size which is the average of the range observed, e.g., if the particles are in the range 1–5μ, their size is given as 3μ. Improved results can be obtained by the use of wet slides, when the powder is mixed with a suitable carrier, e.g., mineral oil, benzine, varnish, glycerine, etc.

A modern innovation is the use of a scanning beam from a television tube to run across a projected field several times and count the particles of various sizes. It is also possible to measure the transmitted light by means of a photoelectric cell, and from this calculate particle size.

For still smaller sizes, the electron microscope can be used, the main difficulty being that one can only measure a relatively small number of particles at one time. Particles down to 0·003μ can be measured, and irregularity and porosity are more readily observed.

Particles that pass through the finest sieves are usually rather difficult to measure by microscope and the operators readily tire. There is need, therefore, for some other means of measuring them.

Sub-Sieve Range

In this range, the particle size must be determined by methods in which powder is dispersed in liquids or gases of known viscosity. The particles fall through a stationary fluid at a rate determined by Stokes' Law, in such a way that the larger the particle the faster it falls. Particles be can measured over the range 1–100μ; particles of size greater than 100μ fall too quickly, and those less than 1μ are subject to the Brownian movement.

The rate of settling is a complex function of:

(*i*) Mean size.

(*ii*) Shape.

(*iii*) Nature of the surface.

(*iv*) Agglomeration or lack of dispersion.

Variables occurring in the fluid are:—

(*a*) Viscosity

(*b*) Density

(*c*) Surface tension

(*d*) Molecular structure

(*e*) Wall effects.

To understand the process of sedimentation a brief survey of Stokes' Law must be made.

Stokes' Law correlates mean particle size and settling velocity, essentially for spherical particles. When speaking of Stokes' diameter of irregular particles it is the diameter of a sphere of the same sedimentation properties as the particle to which it is related. The relationship between the Stokes' diameter d_s to the true size d_T is rather complicated.

Stokes' diameter is given by

$$d_s = \sqrt{\frac{18\,\phi v}{(w-p)\,g}}$$

where w = particle density in g./cc.

p = density of fluid in g./cc.

ϕ = viscosity of fluid in poises

v = terminal velocity in cm./sec.

This basic law has been modified for irregular particles according to Einstein and Oseen to give

$$d_s = (1 + 0{\cdot}095R_E)\sqrt{\frac{18\,\phi v}{(w-p)\,g}}$$

where R_E is the Reynolds number, which should not exceed 0·2 for consistent results. If the Reynolds number is above 0·2, one runs into the risk of eddy current formation during settling. Normally there is a practical limit to the particle size which can be determined by these methods.

Sedimentation Methods

Sedimentation and Decantation

This method consists of decanting a known weight of powder in a suitable dispersing medium after various time intervals. The usual apparatus is a 1-litre beaker marked 2·5 cm. from the bottom and 12·5 cm. from the bottom. The syphon consists of a bent glass tube and is arranged so that its short upward bent end is level with the mark at 2·5 c.m

A suitable dispersive agent, such as Teepol or other commercial wetting agent, is added to the liquid suspension before test in order to achieve uniform dispersion. The metal particles are allowed to settle for a time t seconds, after which the liquid is decanted by means of the syphon from the 12·5 cm. mark to the 2·5 cm. mark. Thus all particles retained in the suspension in this depth of 10 cm. (s) are removed by the decantation.

The fraction is evaporated to dryness and weighed and a suitable correction applied for the amount of non-volatile dispersive agent remaining on the powder. The residue left in the beaker contains all the particles whose settling velocity is greater than s/t. While the decantation portion contains all the particles settling more slowly than s/t.

If the determination is repeated for various values of t, the weight of powder of settling velocity V_A to V_B can be estimated, where V_A is the upper and V_B the lower limit of velocity for a given range of t. For really accurate work, about 6 fractions are taken, and the whole test repeated several times with the same powder and suspension medium. This method gives a very accurate picture of the particle size distribution of a fine powder.

Elutriation in Liquids

Particles in a vertically rising liquid current of velocity V_L are carried up if their settling velocity is less than that value. The nett upward velocity of a particle will be $(V_L - V)$ (where V is the particle settling velocity). An example of this type of apparatus is the Cooke short column elutriator commonly used in the powder metallurgy field on sub-sieve particle analysis. The major snag with the method is the length of time taken to separate particles whose settling velocity V is taken nearly equal to V_L.

It is best practice to separate the smaller size particles first, so that a continuous test can be carried out. If the larger particles are separated first, they carry over all the particles smaller than the specified size, and thus it

becomes necessary to carry out several tests to get a distribution curve.

Air or Gas Elutriation

Elutriation in gases is similar in principle to the methods used for elutriation in liquids, except that the lower size limit is raised to 5μ, instead of about 2μ for liquids. One of the advantages of elutriation with gases is the fact that the powder particles are not "wetted." Thus, one of the methods used, i.e., the Roller Air Analyser provides a practical method for separating a mixture of particle sizes into various ranges.

For laboratory purposes, the Haultain Infra Sizer, which consists merely of a cylinder of accurately calibrated diameter, may be used. Other instruments that can be used are the Federal Classifier, the Micromerograph, the Campbell Elutriator, and the Roller Analyser. All of these instruments are mechanically similar to the Haultain Infra Sizer, but have different methods for the control of gas flow.

It will be appreciated that a cylinder of accurately-known diameter into which a gas is passed at a known volume rate of flow gives an accurately measured rate of flow. In these instruments, particles having a settling velocity greater than the speed of gas flow drop to the bottom of the cylinder, while other particles are carried out of the top.

Pipette Method

This method uses an Andreasen pipette, the principle being that a weighed sample of powder is shaken with a suitable dispersing medium in the cylinder of the pipette. 10 cc. samples are removed at measured intervals by means of the pipette, and the settling depth noted before removal of the sample. The fractions are evaporated to dryness and weighed, and the settling velocity computed.

The pipette method is simple and quick and is quite reliable, but a mixture of powders of different particle densities will give different settling velocities for each density, and, consequently, variable ratios of size to time will be obtained according to the amount of one powder mixed with another.

Hydrometer Method

This method uses a normal hydrometer giving direct reading of specific gravity. The readings are taken at regular intervals, and the change in specific gravity due to the settling velocity noted. It is necessary to know the settling height in order to plot a graph of the specific gravity reading (R) against settling height (S).

The settling height S is given by :—

$$S = h_R + \tfrac{1}{2}\left(h + \frac{V}{A}\right)$$

where h_R = distance of the scale reading from the top of the hydrometer bulb.
V = volume of the hydrometer bulb.
A = area of vessel used.
h = height of the bulb.

The accumulative percentage of powder remaining in suspension, y, for a given reading R is :

$$y = K\,(R - r)$$

where r is the hydrometer reading in pure liquid.

The constant K is unchanged in any one experiment and is :

$$K = \frac{10^5 p}{W_0\,(p - r)}$$

where p is the density of powder and W_0 the dry weight of sample taken. The temperature of the vessel and contents must be kept constant or corrections made for change in density.

Turbidometer Method

The Turbidometer actually measures specific surface, and depends on the principle that the specific surface of particles in suspension in a transparent medium is related to the decrease of light intensity when a light source of known strength is shone through a suspension of measured concentration.

One method is to use the Spekker absorptiometer, which is now in common use for chemical analysis. This consists of a central light source which passes two diametrically opposite beams to balanced photo-electric cells. By placing a suspension of metal powder in a suitable medium between the light source and one photo-electric cell, and measuring the current developed when a cell containing clear liquid is inserted between the light source and the other photocell, the amount of light absorbed can be estimated.

Although the mathematical theory is rather complex, the method is based upon equation

$$S = K \log \frac{I_0}{I}$$

where K is a constant which must be determined experimentally, S is the surface area of the suspended particles, I is the intensity of the light source shining through the suspension and I_0 the intensity of light passing through the clear liquid.

The specific surface is related to diameter by quoting the size of a sphere of equivalent surface. It is evident, therefore, that the Turbidometer only gives the Stokes' diameter, and is subject to error due to currents within the liquid medium. Various other instruments may be used, but depend on the same principle and are operated in a similar manner.

Gravimetric Method

Many methods have been devised for weighing the amount of powder which settles on a given area from a suspension in a known time. None of these methods is entirely successful, since movement of the balance pan which occurs when particles are deposited sets up currents within the fluid. The method is amenable to recording, is extremely simple to operate, and suspensions can be left to settle indefinitely.

New Techniques

There are several other methods for measuring particle sizes which have been developed recently, and which cannot be classified into any of the groups previously mentioned. Among these may be mentioned the measurement of the permeability of loose packing of a powder : this measures the total surface, and sizes must be calculated on the assumption that the particles are spherical. In a similar way, absorption of dyes or gases by known weights of powder will give an estimate of the total surface area. It is also possible to measure the rate of solubility or chemical reaction rates to estimate surface areas. Another method suggested for surface area measurement depends on the estimation of isotherms within a suspension in which the powder is partially soluble.

All of these latter methods are essentially laboratory techniques used in advanced research, largely for cross-checking other methods.

Conclusions

In this brief survey, the basic principles underlying the more important methods for estimating particle size have been given. The importance of accurate measurement of sizes below 50μ has only recently been confirmed. It is possible to obtain two powders of the same composition and sieve size, but with different sub-sieve sizes, which show markedly different physical properties.

The measurement of particle sizes is of particular importance when mixtures of metals and non-metals are being made for powder metallurgy purposes. Thus, these measurements are of great importance in the manufacture of carbides and metal-bonded ceramics for high temperature service.

It may be thought that particle size measurement is of importance only when using metal powders. This is not correct, since particles such as blood cells, dusts, refractory materials, clays for ceramics or even colloidal materials, need to be measured. Although most of the present advances in particle size measurement relate to powder metallurgy, this is only because metal particles will remain constant in size for long periods. Once a method has been proved satisfactory, it may be applied to other fields.

In conclusion, it may be remarked that particle size measurement is a highly specialised field, and one which is likely to lead to confusing results. When measurements are being made industrially the greatest care is necessary to ensure accuracy, but many methods have been rendered automatic and can be operated by unskilled persons.

BIBLIOGRAPHY

1 Goetzel, C. G. "Treatise on Powder Metallurgy—Vol. I," 1950, New York, Interscience Publishers.
2 Schwarzkopf, P. "Powder Metallurgy," 1947, New York, MacMillan.

B.T.H. Rolling Mill Drive Order

An order valued at £750,000, covering the electrical equipment for a 4-stand tandem cold strip rolling mill, has been placed with the British Thomson-Houston Company by the Steel Company of Wales, Ltd. The mill is to be installed at Abbey Works, Port Talbot, and is for the rolling of steel strip up to 50 in. wide at a maximum speed of 3,500 ft./min. There will be four rolling stands, each driven by a separate motor, followed by a tension reel, also with its own motor.

The electrical equipment to be supplied by B.T.H. will comprise one 3,500-h.p., three 5,000-h.p. and one 1,250-h.p. D.C. motors, two synchronous motor-generator sets for supplying the motors, and a large quantity of control gear. The motors are of the very low inertia type having high length/diameter ratio, and were specially developed by B.T.H. for the Steel Company of Wales' cold tandem mills at Trostre and Velindre. The machines and scheme of control will follow the same general lines as used for the Velindre 5-stand mill which has recently gone into such successful operation, but B.T.H. is introducing a number of advanced features into the design.

Ore Handling Plant for Belgium

The Fraser & Chalmers Engineering Works of The General Electric Co., Ltd., has received contracts to the value of some £200,000 from Forges de la Providence S.A. of Marchienne-au-Pont, Belgium, for ore blending, crushing, screening and sampling equipment. Low-grade iron ore from the Briey district and imported Swedish ore will be handled by the blending equipment, densities varying from 1·6 to 3·2 tons/cu. m.

A double-wing travelling stocking tripper is designed to feed both the Briey and Swedish ores into four blending and storage piles, each pile having an average capacity of 17,000 metric tons when ore of a density of 2·2 tons/cu. m. is handled. Rated output of the transverse conveyors on each arm of the stacker is 600 tons/hr. when feeding Briey ore to the piles, and 800 tons/hr. handling Swedish ores.

Blending and recovery of the ores will be carried out by two Robins-Messiter reclaiming machines operating simultaneously from the extremity of any pile; the machines consist essentially of a reciprocating harrow and a plough conveyor delivering blended ore to a longitudinal conveyor placed outboard of the piles. Blended ore will be recovered by the reclaimers at a rate of 450 tons/hr.

Two Symons 5½ ft. standard cone crushers, manufactured by the Fraser & Chalmers Engineering Works, form part of the equipment required for a crushing plant. Reduction in the ore from a maximum size of 320 mm. to minus 65 mm. is effected with an output of approximately 300 tons/hr.

Both primary and secondary separation will be effected at the screening plant by Gyrex mechanically-vibrated screens. Two lines of single-deck screens will operate in parallel with primary screening to separate a minus 25 mm. fraction. Distribution by Sherwen electromagnetically vibrating feeders will be made to secondary Gyrex screens, arranged with screen cloth heating, to effect a final separation of the minus 10 mm. fraction.

Equipment for a sampling plant, consisting of three 24 in. × 18 in. Larne roll crushers and several Sherwen feeders is also on order for handling minus 65 mm. ore with a reduction to 15/20 mm. at the primary sampling station and a final feed of minus 3 mm. at subsequent stations.

Consultants to Forges de la Providence S.A. are John Miles and Partners of London, E.C.3.

New Peribonka Hydro Electric Scheme

Aluminium Limited recently announced a new hydro-electric power development of one million horse-power on the Upper Peribonka River in Northern Quebec. The Company's action followed an announcement by the Provincial Government that official leases of the water rights on the river had been issued to Aluminum Company of Canada, Ltd.

Correction

A Direct-Reading Phase Counter for Metallurgical Specimens

We regret that in the printing of the above article, which appeared on pages 157–158 of our September issue, particulars were omitted of the two papers to which reference was made in the text. The references concerned are :—

1 Shand, S. J. Journal of Geology, Vol. 24, 1916, 394.
2 Callis, G. T. and Moore, R. S. *Metal Industry*, August 4th, 1950.

The Application of the Hilger Direct Reading Attachment to the Spectrographic Analysis of Hiduminium RR.50 Type Alloy

By E. C. Mills, F.R.I.C., and S. E. Hermon

Research Division, High Duty Alloys Limited, Slough.

Experimental work on the application of the Direct Reading attachment to the analysis of a commercial alloy by the Hilger Medium Quartz spectrograph has shown the attachment to be capable of giving better results than are obtained by the normal photographic technique, with considerable improvement in speed and greater reliability in use. With certain complex alloys there seemed to be a need for a more versatile spark source.

IT has always been the policy of High Duty Alloys, Ltd., to use modern instrumental methods to maintain the best possible analytical control of their products. Since 1939, therefore, the spectrograph has found ever increasing use; the advantages of this method over the classical wet procedures being well known.

During recent years, spectroscopic equipment has been made available to industry which eliminates the use of the photographic plate and the attendant difficulties of line density measurement. Instead of forming a latent image in a photographic emulsion, light of the desired wavelengths is selected and allowed to fall on the sensitive areas of photo-electron multipliers, and the signals so formed are amplified and can be observed on a meter or chart recorder. This greatly increases the speed with which results are obtained, and in many cases there is considerable improvement in reproducibility, with an associated improvement in accuracy.

To make practical use of these advantages, an A.R.L. Production Control Quantometer was installed in one of our Production Divisions in 1953, and within a comparatively short time this instrument was able to analyse successfully the majority of a wide variety of alloys encountered in the Division. Primarily as a result of the very high speed of analysis, it was possible to improve still further the quality of the Company's alloys. The Quantometer and other similar apparatus are complete units designed specifically for the direct reading analysis of a large number of elements*, and to justify the purchase of such comprehensive equipment the volume of work to be handled should be sufficiently great.

Hilger Medium Quartz spectrographs are still used in the Company for analysing up to 10 elements with a maximum content level of about 3%. As part of a general programme of spectrographic research, it was planned to construct a four photo-electron multiplier, direct reading attachment for one of these instruments, to avoid the limitations imposed by the photographic plate. By so doing, it was hoped to obtain some of the many advantages shown by the Quantometer, but with relatively small expense. About the same time, however, Messrs. Hilger and Watts, Ltd., were developing an attachment for their Medium Quartz spectrograph, incorporating a maximum of 11 photo-electron multi-

* At the time of writing, the Quantometer at Distington is set up for the analysis of 22 different elements in aluminium alloys.

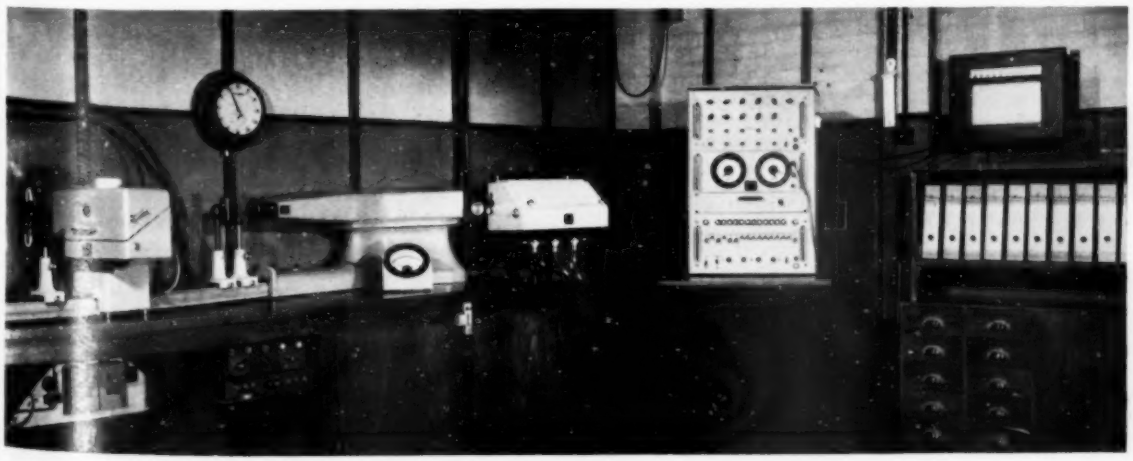


Fig. 1—Hilger Medium Quartz spectrograph with Direct Reading attachment at High Duty Alloys, Ltd., Slough.

pliers. Our own programme was abandoned, therefore, in favour of this commercial equipment, which was installed in our Research Division for a preliminary assessment of its possible application to the control analysis of aluminium alloys. (Fig. 1).

The initial experimental work covered the analysis of a number of aluminium alloys, and this article gives an example of the application of the Hilger Direct Reading attachment to one common production alloy, Hiduminium RR.50. The work demonstrated that the attachment is capable of giving a degree of accuracy, reproducibility and stability comparable with that obtained by good photographic techniques under research conditions, and superior to normal production control simplifications of these techniques. At the same time, for the particular elements covered, the speed of analysis is comparable with that of other direct reading instruments.

As received, the instrument was set up for the following element lines :—

Element	*Wavelength* (Angstrom)
Copper	2247
Cobalt	2286
Iron	2382
Silicon	2514
Manganese	2593
Aluminium	2660
Magnesium	2790
Chromium	2843
Zinc	3345
Nickel	3493
Titanium	3685

The width of the spectrographic slit is 25 microns and the element exit slits are each 50 microns. A simple condensed spark source unit was used, based on the Hilger F282 transformer, with additional capacity of 0·008–9 μF and inductance of 0·03–0·08 mH. The RF current flowing in the analytical gap was 3–5 amp. and the pre-integration (pre-spark) and 'auto' integration (exposure) times were 10 and 25–30 seconds respectively. The electrodes were of the cast pin type normally used for production control purposes. These were held in a horizontal spark stand and used as self electrodes, as in previous work on photographic techniques. The standards of the alloy type chosen covered the following ranges :

Copper	0·8 –2·0%
Magnesium	Up to 0·3%
Silicon	1·5 –3·2%
Iron	0·7 –1·7%
Manganese	Up to 0·15%
Nickel	0·6 –1·8%
Titanium	0·05–0·25%
Zinc	Up to 0·15%

Tests were conducted to assess the following :—

(*a*) Reproducibility of determinations.

(*b*) Stability of the calibration graphs.

(*c*) The degree of accuracy possible.

Notes on these tests, together with the results obtained, are given below.

Reproducibility of Determinations

Reproducibility experiments were carried out on 24 sparkings, using 48 individual pencils of a selected standard sample, the composition of which is given in Table I. The standard deviation (coefficient of variation) was calculated by reference to a graph obtained by sparking standards with the samples. The standards were each sparked in triplicate and the average readings used to plot the points of the graph.

The results are shown in Table I, together with results obtained using similar excitation and electrode conditions and normal spectrographic techniques (10 seconds pre-spark/60 seconds exposure).

TABLE I

Element	Composition %	Direct Reading Attachment		Spectrograph	
		σ	S	σ	S
Copper	1·54	0·042	2·71	0·065	4·20
Magnesium ..	0·154	0·0095	6·22	0·0127	8·25
Silicon	2·54	0·041	1·60	0·083	3·25
Iron	1·13	0·043	3·80	0·032	2·85
Manganese ..	0·049	0·001	1·86	0·0024	4·15
Nickel	1·10	0·025	2·31	0·042	3·85
Titanium	0·125	0·047	3·76	0·053	4·20
Zinc	0·12	0·0052	4·33	*	*

* Zinc is not normally determined on the spectrograph

These tests were repeated at different intervals, very similar results being obtained. In every case, standard deviations superior to those with normal photographic methods were found to be possible.

Detailed examination of the individual Direct Reader results showed that little improvement in the standard deviations was obtained, if these were calculated using the averages of duplicate sparkings (i.e., taking sparking results in consecutive pairs). In addition, there was no significant drift from the beginning to the end of a batch.

Stability of the Calibration Graphs

Calibration graphs were constructed on triplicate sparking of three standard alloys sparked at hourly intervals. From each set of graphs, the readings for a typical specification alloy were read off. The Direct Reader equipment was not used between each series of tests, but the source unit was kept in intermittent operation by means of a Sunvic control, to simulate routine control operating conditions. The laboratory temperature was increased progressively over a range of 6° F. throughout the day, and the head compensated accordingly. The readings obtained are given in Table II.

TABLE II

Time (hr.)	Cu	Mg	Si	Fe	Mn	Ni	Ti
	8 min.	8 min.	9 min.	8 min.	9 min.	10 min.	8 min.
10·00 ..	30·8	18·9	48·3	34·5	19·4	43·7	56·0
11·00 ..	30·8	18·4	48·3	35·8	19·5	44·6	55·9
12·00 ..	30·8	19·0	48·3	34·2	19·5	44·5	56·0
13·00 ..	30·8	18·2	48·0	34·2	19·4	43·9	54·9
14·00 ..	30·2	18·4	47·4	35·5	19·4	43·5	54·3
15·00 ..	30·8	18·6	48·3	34·2	19·7	43·3	53·7
16·00 ..	29·8	19·1	47·2	32·8	19·4	43·2	53·4
17·00 ..	29·6	19·1	47·2	34·5	19·2	42·8	53·6

Table II shows that, except for the titanium channel, which contained a photomultiplier with poor characteristics*, the graphs were stable over the normal working day and gave better agreement than is possible from plate to plate. Fig. 2 shows the type of graphs obtained, which are either straight lines or gentle curves.

Accuracy

Three typical production alloy samples were analysed chemically and by the Direct Reader, on a number of separate occasions. Calibration graphs were constructed

* This trouble was cleared subsequently by fitting a new photo-electron multiplier.

on each occasion, using triplicate sparkings of the alloy standards, and the average of triplicate sparkings of the alloy samples was interpreted from the curves. The results are given in Table III.

TABLE III

	Sample	Cu %	Mg %	Si %	Fe %	Mn %	Ni %	Ti %
Chemical Analysis	81	0·98	0·057	2·32	1·00	0·02	0·89	0·170
A	81	0·98	0·067	2·31	0·97	0·016	0·88	0·144
B		0·97	0·057	2·32	0·99	0·015	0·86	0·130
C		0·97	0·064	2·39	0·99	0·015	0·87	0·150
D		0·97	0·061	2·34	1·00	0·018	0·86	0·132
E		0·99	0·055	2·38	1·01	0·014	0·86	0·135
F		0·98	0·065	2·35	1·00	0·015	0·88	0·137
Chemical Analysis	82	0·98	0·071	2·34	0·99	0·02	0·89	0·204
A	82	1·00	0·075	2·35	0·98	0·017	0·88	0·182
B		0·98	0·070	2·32	1·00	0·016	0·82	0·170
C		0·94	0·073	2·32	0·97	0·015	0·84	0·170
D		0·96	0·066	2·30	0·99	0·017	0·84	0·164
E		0·98	0·066	2·33	0·98	0·015	0·85	0·166
F		1·01	0·073	2·36	1·00	0·015	0·87	0·176
Chemical Analysis	83	0·98	0·085	2·33	0·99	0·02	0·90	0·184
A	83	0·99	0·085	2·36	0·98	0·017	0·89	0·154
B		0·98	0·074	2·34	0·98	0·015	0·88	0·153
C		0·97	0·076	2·39	0·99	0·015	0·88	0·160
D		0·98	0·077	2·36	1·02	0·018	0·86	0·146
E		1·02	0·087	2·40	1·02	0·015	0·88	0·160
F		1·03	0·085	2·42	1·01	0·016	0·91	0·159

There is consistently good agreement between the Direct Reader and chemical results for all elements except the minor element titanium. (Good results were obtained for titanium after replacement of the photo-electron multiplier). There is also good reproducibility from occasion to occasion. It was also shown that if duplicate instead of triplicate sparkings were used to calculate the content of the samples, the accuracy was still satisfactory, unless a definitely erratic sparking were present. In practice, using the Direct Reader, an erratic sparking can be detected instantly, and can be rejected and resparked. Further tests were carried out over the full compositional range given above. These also gave agreement with chemical figures.

Speed of Analysis

The Direct Reading attachment gives a very high speed of analysis, as shown by the following timing sequence. The total time is from when the start button is pressed.

Earthing period	4·5 sec.
Pre-integration period	4·5 sec.
Integration period	25 sec.
Measurement of 8 elements	36 sec.
Total time for the analysis of 8 elements	70 sec.

In analysis, the only remaining operation is to read off the percentage compositions from the appropriate calibration charts. This can usually be done simultaneously with the appearance of each reading. The ultimate effect of this increased speed is seen from the fact that, in the reproducibility experiments described above, the time for the complete operation, including the calculation of the standard deviations, is half that taken for the conventional spectrographic results.

The improved speed is brought about by avoiding the processing of the photographic plates, thereby eliminating the use of the microphotometer and the subsequent calculation of line density ratios. The Direct Reader gives electronically the equivalent of line ratios by using the aluminium base line as a control.

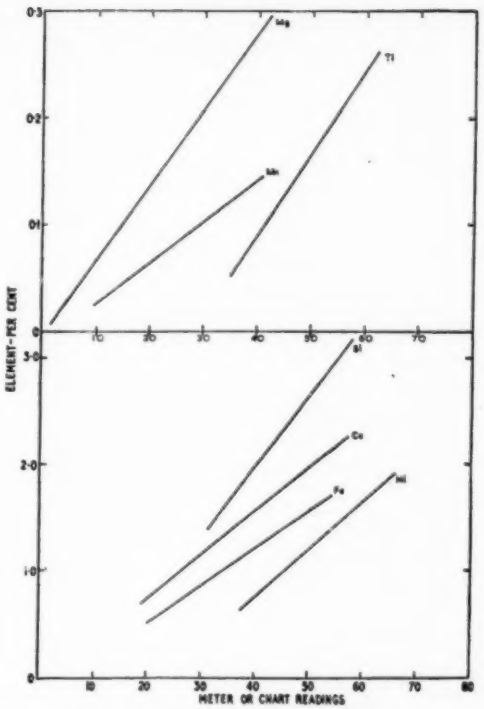


Fig. 2—Typical calibration graphs.

Conclusions

The experimental work on the Hiduminium RR.50 type of aluminium alloy has shown that the performance of the Hilger Direct Reading attachment is such that better results are obtained than by the normal photographic technique, with considerable improvement in speed and greater reliability in use. The latter results mainly from the simplicity of operation of the equipment

Although one is not limited by the characteristics of the photographic plate, a compromise has to be made in the selection of lines to cover all alloying compositions which are likely to be analysed on the particular instrument. In a preliminary investigation on the application of Direct Reading analysis to a variety of aluminium alloys, it was noted that, with certain complex alloy types, there appeared to be a need to use a more versatile spark source than the simple source now employed, mainly because the simple source does not seem to be capable of giving the necessary degree of excitation in these cases. Experience will be necessary to decide upon the best source unit and the most suitable electrode geometry for use with the Direct Reading equipment.

Acknowledgment

The authors wish to acknowledge the help given by their colleagues in the Research Division, and to thank the Directors of High Duty Alloys Ltd. for permission to publish these results.

REFERENCES.

1 Mills, E. C. and Hermon, S. E., *Metallurgia*, 1953, **48**, (276), 213-215.

2 Mills, E. C. and Hermon, S. E., *Metallurgia*, 1953, **48**, (288), 209-211.

The Polarographic Determination of Zinc in Aluminium Bronze

By D. R. Curry, B.Sc., A.R.I.C.,* and Miss J. T. King-Cox

Bragg Laboratory, Naval Ordnance Inspection Department

The possibility of evolving a rapid method for the determination of zinc in aluminium bronze has been examined. A method is proposed which, after precipitation of copper with aluminium, separates zinc with the aid of a centrifuge by caustic soda extraction. Interference due to the solubility of iron hydroxides is noted, and found to be a constant for practical purposes.

THE potentialities of the polarographic method have only been investigated in the present research programme where a specific deficiency in the current routine procedures was apparent. The latter are generally classical (volumetric or gravimetric), or utilize absorptiometric finishes with aqueous solutions. Polarographic methods were only sought if a considerable saving in time might be effected, or a higher degree of precision attained.

A particular demand where both the criteria mentioned above are operative was the determination of zinc in complex aluminium bronzes. Although the general specification limit is 0·5% max., frequently figures are required below the 0·05% level. The general composition of these alloys is :—

Cu	Al	Fe	Ni
80%	10%	5%	5%

while 1% manganese and other elements in small amounts may be present.

Zinc is well-known as giving excellent polarographic waves, particularly in ammoniacal media.[1] No colorimetric method is available, and the potential sensitivity of the polarographic method makes an investigation worthwhile.

General Considerations and Preliminary Experiments

The $E_{\frac{1}{2}}$ values for zinc in all the common supporting electrolytes are in the region of — 1·0 to — 1·5 volts *v.* S.C.E., and in most cases there will be preceding waves of copper and nickel. Zinc is not reducible in the cyanide medium so favourable for the determination of nickel in copper-base alloys.[2]

A fairly rapid method capable of routine application, both from the chemical and polarographic standpoint, was required. This ruled out extraction procedures or lengthy filtration as separation techniques, and the use of the derivative polarogram.†

Initially, experiments were carried out utilizing the electrolyte after the normal removal of copper in the routine composite procedures. The nature and strength of the acidity were responsible for failure in this direction, as nitric and sulphuric acids are not so desirable polarographically as hydrochloric acid. The total normality approximated to 2·5N when concentrated to 50 ml. volume per 0·5 g. sample. Polarographic waves for zinc are only produced at the dropping mercury electrode in alkaline solution, as in acid media hydrogen precedes them.

Some attempts were made to obtain a wave by evaporating the electrolyte to low bulk, neutralizing with ammonia and adding an ammonia, ammonium chloride, gelatine-base electrolyte. This precipitated the iron, and further addition of ammoniacal dimethylglyoxime precipitated the nickel. Apart from the tedious evaporation, the final polarograms were unreliable, whether the solutions were filtered or not.

First Tentative Method

Consideration was then given to the well-established method of Stross[3] for the determination of zinc in aluminium alloys of all types. This involves repeated caustic alkaline extraction of the zinc (and aluminium): in the case of copper-base alloys, initial solution could not be effected in caustic alkali, but the alloy was readily opened up with hydrochloric acid and hydrogen peroxide. Accordingly, the following procedure was adopted :—

> Dissolve 0·5 g. sample in 5 ml. 5 N hydrochloric acid. with four 1 ml. additions of hydrogen peroxide (100 vol.). Add 5 ml. 40% sodium hydroxide, centrifuge and decant. Dissolve residue in 5 ml. 5 N hydrochloric acid and 1 ml. hydrogen peroxide (100 vol.). Reprecipitate and centrifuge as before. Extract the residue with 2 ml. 40% sodium hydroxide, centrifuge and decant. Transfer the combined centrifugates to a 50 ml. graduated flask, dilute with water and record the polarogram.

A certain amount of copper was carried through with this procedure, and, consequently, maximum zero correction was required to permit a reasonable sensitivity for the zinc wave when recording the polarogram. It was also found that the shape of the zinc wave was improved by the presence of gelatine. Apart from the undesirable break-through of the copper, it was felt that the considerable bulk of the precipitate made co-precipitation losses of zinc probable, even with double precipitation and extraction.

The procedure was then modified to remove most of the copper by precipitation with zinc-free aluminium powder, and the following method has been found satisfactory.

Proposed Method

Reagents

Hydrochloric Acid (5*N*)—430 ml. Polaritan hydrochloric acid (s.g. 1·18) diluted to 1 litre with water.

* Present address: S.E.R.L., Baldock, Herts.

† While the derivative technique is of great value in research and trace analysis, it is not considered suitable for routine application, as it is time-consuming and delicate, except in idealised solutions.

Sodium Hydroxide (40%)—200 g. AnalaR sodium hydroxide pellets dissolved in water and diluted to 500 ml. (stored in a polythene bottle).

Hydrogen Peroxide (100 *vol.*)—AnalaR quality.

Gelatine (0·2%)—0·2 g. Polaritan gelatine dissolved in 100 ml. warm water.

Aluminium Powder—Coarse, zinc-free.

Special Apparatus

Centrifuge—Multihead centrifuge fitted with 45 ml. lipped centrifuge tubes with hemispherical bottoms.

Polarograph.—In the present work a Tinsley Mk. 15/6 has been used. Owing to the small size of the top plateau of the zinc wave, a manual instrument might be unsuitable for this method.

Procedure

Transfer 0·5 g. alloy drillings to a 125 ml. conical beaker and add 5 ml. hydrochloric acid (5N). Cautiously add four 1 ml. portions of hydrogen peroxide (100 vol.) to effect complete solution. When reaction has subsided, boil for a few minutes to remove excess peroxide and cool.

Add 150 mg. of aluminium powder to precipitate the copper and filter through a 9 cm. Whatman 541 paper, collecting the filtrate in a centrifuge tube; wash with the minimum of water (a pleated filter paper should *not* be used as it cannot be washed so readily).

Add 5 ml. sodium hydroxide to the contents of the centrifuge tube, and stir thoroughly with a small glass rod until an even consistency of precipitate is obtained. Centrifuge and decant into the original beaker. Add 5 ml. of hydrochloric acid to the residue in the centrifuge tube, and stir until a clear solution is obtained (ignore any slight turbidity due to aluminium hydroxide). Add 5 ml. sodium hydroxide, centrifuge, and decant as before. Add to the residue 1 ml. sodium hydroxide and approximately 2 ml. of water. Stir thoroughly to mix the residue with the solution, centrifuge and decant. Add 1 ml. gelatine solution to the combined centrifugates, and dilute with water to 50 ml. in a graduated flask. After mixing, transfer a portion to a polarographic cell, remove dissolved oxygen by bubbling with nitrogen, and record the polarogram.

$E_{\frac{1}{2}}Zn = -1{\cdot}3$ volts *v.* Mercury Pool Anode

Results

The above method gave good waves and excellent linearity of calibration when carried through on an actual aluminium bronze sample with known increments of standard zinc solution up to 0·10% additional zinc. The "blank" of the calibration graph equivalent to the zinc content of the sample, was, however, somewhat higher than the content determined by the normal chemical method. The value of this error was about 0·05% zinc, and as this was the same order as the content it was desired to measure in samples, the "blank" value had to be eliminated, if possible, or at least reliably evaluated.

Investigation of 'Blank'

Reagents

The various reagents were first examined separately with a view to confirming their purity.

The specification for AnalaR sodium hydroxide (0·002% zinc max.) could give the equivalent of 0·02% zinc in the final solution owing to the high concentration. Whilst this report was in preparation it was noted that potassium hydroxide is recommended as preferable to the sodium salt for polarography of zinc.[4] It is also realised that potassium hydroxide is available as a Polaritan grade, but the specification would still admit a similar error.

None of the reagents—hydrochloric acid, sodium hydroxide or hydrogen peroxide—showed any trace of zinc or other ion manifesting itself as zinc in the final determination. The aluminium powder was shown to be zinc-free spectrographically.

Synthetic Mixture

A synthetic aluminium bronze solution was then prepared as follows:—

8 g. AnalaR copper
1 g. aluminium powder
0·5 g. Specpure nickel
0·5 g. Specpure iron

} dissolved in 100 ml. hydrochloric acid (5N) and 80 ml. hydrogen peroxide (100 vol.), diluted to 200 ml.

10 ml. aliquots of this solution, each equivalent to 0·5 g. samples, with known additions of standard zinc solution, were carried through the procedure. A good calibration graph was obtained showing a definite "blank" (which should in this case have been zero). The "blank" was accordingly attributed to an interference by one of the components of the aluminium bronze. This could only arise from copper, nickel or iron, as the method was parallel in principle to the aluminium alloy method,[3] which was free from interference.

Pure salts of these metals were polarographed in the sodium hydroxide solution, with and without standard additions of zinc. Iron was found to give a wave at the same $E_{\frac{1}{2}}$ value as zinc while the other metals did not interfere.

The Solubility of Iron Hydroxides

Reference to the literature [5, 6] showed that a wave for iron had been observed in strong alkaline solutions saturated with ferric hydroxide.

It was observed that, after standing overnight, a small quantity of ferric hydroxide was precipitated from the solutions. On filtering this off, polarograms recorded showed a decrease in wave height, but agreement between duplicates and linearity of calibration was poorer than with the fresh solutions.

The "blank" was shown not to have a consistent value for every set of solutions made up, and so had to be eliminated. Filtering the fresh solutions did not remove the interference, which was assumed to be due to colloidal ferric hydroxide. The addition of approximately 0·2 g. Whatman Ashless Floc, however, followed by thorough shaking and filtration through a Whatman fluted filter paper into the polarograph cell, was effective in removing the iron. In this way, the "blank" was reduced to a lower value, equivalent to 0·015% zinc, which was reproducible from one set of solutions to another.

General Notes

(1) An additional polarographic hazard in the method has been the use of strong caustic solutions which attack the glass capillary. As a result, drop times are not reliable from day to day for a given height of reservoir above a given capillary. Accordingly, two standards are carried through with each batch of samples for calibration purposes.

(2) After the addition of sodium hydroxide, precipitation of hydroxides and centrifuging, the centrifugate may be blue in colour. This is due to the presence of colloidal

copper hydroxide, which is polarographically active. However, this is removed with the ferric hydroxide by shaking with floc and filtering, when the filtrate should be colourless.

Results and Conclusions

No standard figures are available at the 0·05% level that can be relied upon, but the following results were obtained using samples with somewhat higher values.

Sample No.	Zinc Determined Chemically (%) (mean of three determinations)	Zinc Determined Polargraphically (%)
MN 156	0·11	0·10, 0·10, 0·12, 0·12*
MN 160	0·12	0·11, 0·11, 0·11
EN 1089	0·22	0·19, 0·21, 0·24, 0·20, 0·20

* Values obtained using the proposed method, including calibration.

The method evolved was not intended to be of referee standard, but the speed and sensitivity desired have been obtained. Despite the drawbacks of blank and calibration, the procedure is adequate for routine analysis. A set of four samples with standards can be carried through in 3–4 hours.

Acknowledgments

Thanks are due to Dr. W. Stross (International Alloys, Ltd.), for his interest and helpful suggestions.

This paper is published by permission of the Admiralty.

REFERENCES.

1 Kolthoff, I. M. and Lingane, J. J. "Polarography," Vol. 2, 503 *et seq.*, New York, 1952, Interscience Publishers.
2 Milner, G. W. C. *Analyst*, 1945, **70**, 468.
3 Stross, W. *Metallurgia*, 1947, **36**, 213.
4 Dirkse, T. P. *Z. Phys. Chemie Neue Folge*, 1955, Sept., **5**, Heft 1/2 1.
5 Kolthoff, I. M. and Lingane, J. J. "Polarography," Vol. 2, 478, New York, 1952, Interscience Publishers.
6 Heyrovsky, J. "Polarographie," Vienna, 1941, 191.

International Conference on Precision Casting

REPRESENTATIVES of about thirty precision casting foundries attended a conference held in Europe earlier this year. A number of lectures on technical subjects, a visit to the Philips Works, and a trip to the bulbfields gave the participants the opportunity to exchange ideas.

The titles of the papers presented were as follows: *A Review of the Properties of Stellite Alloys*, by M. RIDDIHOUGH (England); *Tentative and Finalized Specifications in U.S.A. for Investment Castings*, by V. DI SAMBUY (Italy); *Could Mistakes in the Past in the Precision Foundry be Avoided in the Future*, by B. G. HELDERS (Holland); *The Philips X-Ray Intensifier*, by H. J. MEERKAMP VAN EMBDEN (Holland); *Defects in Precision Castings*, by A. BOUMAN and C. NIEUWENHUIS (Holland); *An Approach Towards the Classification of Casting Defects in Investment Casting*, by W. H. SULZER (Switzerland); *Decarburization in Investment Castings and in Heat Treating*, by N. J. GRANT (U.S.A.), presented by W. A. MATEJKA (Switzerland); *Price Estimation and Cost Calculation in Precision Casting*, F. POLZGUTER (Germany); and *Some Applications of Mathematical Statistics in the Microcast Process*, by J. J. TIEDEMA (Holland).

Participants agreed that these conferences served a useful purpose, and it was unanimously decided to hold the next one in England in 1957.

B.S.I. Annual General Meeting

AT the Annual General Meeting of the British Standards Institution in London on Tuesday, September 4th, a move was made to streamline B.S.I.'s organization by combining the two formerly separate offices of President and of Chairman of the General Council. SIR HERBERT MANZONI (Birmingham's City Engineer), who is already Chairman of Council, was elected the first President under this new arrangement. He succeeds SIR ROGER DUNCALFE, (Chairman of British Glues and Chemicals, Ltd.) who in the past 20 years has held all the principal offices in B.S.I. MR. JOHN RYAN (Vice-chairman of the Metal Box Co., Ltd.) was re-elected Vice-President of B.S.I.

The following were elected, as representatives of B.S.I.'s divisional councils, to serve on the General Council:

Building Division: MR. H. A. PURSEY (Sales Director of Turners Asbestos Cement Co., Ltd.); MR. J. C. TAIT (Senior Quantity Surveyor of the Department of Health for Scotland); and LT. COL. E. VIGOR (Managing Director of the Neuchatel Asphalte Co., Ltd.).

Chemical Division: MR. C. J. CUTBUSH (a director of the Metropolitan Leather Co., Ltd.); MR. G. DRING (Research Director of Bakelite, Ltd.); and SIR KNOWLES EDGE (Managing Director of W. Edge and Sons, Ltd.).

Engineering Division: MR. P. L. JONES (a Director of Swan Hunter and Wigham Richardson, Ltd.); MR. G. L. NEWMAN (Secretary of the Chief Engineer's Committee of Metropolitan-Vickers Electrical Co., Ltd.); and MR. B. E. A. VIGERS (Assistant Managing Director of Laporte Industries, Ltd.).

Textile Division: MR. H. N. AITKEN (Manager of Merchandising and Procurement of Knitted Fabrics Department of British Celanese, Ltd.); Mr. L. F. COCKCROFT (a Director of John Cockcroft and Sons, Ltd.) MR. P. W. GADDUM (a Director of H. T. Gaddum and Co., Ltd.); and MR. E. R. WEST (Research Chemist of Jute Industries, Ltd.).

New T.I. Cycle Subsidiary

TUBE INVESTMENTS, LTD., announce the formation of a new subsidiary, the British Cycle Corporation, Ltd., to take over and control the manufacturing resources of its constituent bicycle companies situated in the Birmingham area, i.e., Armstrong Cycles, Ltd., Brampton Fittings, Ltd., Hercules Cycle and Motor Co., Ltd., Phillips Cycles, Ltd., and Walton and Brown, Ltd.

The manufacture of the well known brands of bicycles marketed by these TI companies will be concentrated in a large factory at Handsworth which has recently been extended. The purpose of this move is to increase efficiency and lower costs for the battle for overseas markets which is being joined with foreign competition. The cycle companies involved will preserve their individuality, and will continue to be responsible for the marketing and development of their particular products.

It is intended that personnel and machinery will be transferred in stages, and as all the factories concerned are in close proximity one to the other, it is hoped that where circumstances call for it, employees will be willing to continue their employment in the new environment.

A Precision Universal Stage for the Microscopical Examination of Fracture Surfaces

By J. F. McNeil, B.Met.E., F.I.M., A.R.A.C.I.
Defence Standards Laboratories, South Australian Branch.

The design and operation of a new precision universal stage suitable for the examination of fracture surfaces at moderate magnifications on an upright metallurgical microscope is described and discussed.

DUE mainly to the work of Zapffe[4], there is developing among physical metallurgists a growing appreciation of the value of direct microscopical examination of fracture surfaces at magnifications of ×100 and higher, both as a means of gaining fundamental knowledge concerning the nature of fracture, and as a method for obtaining information regarding the cause of a particular fracture occurring in service or in testing.

A basic requirement for this type of examination is a device for orientating individual fracture facets normal to the optical axis of the microscope, so that the maximum possible area of each individual facet can be brought into focus, and so that vertical illumination may be employed to best advantage.

Previous Universal Stages

Zapffe and Worden (1949)[4] described a universal stage designed for the above purpose which they have termed a " fractographic stage ". This stage, which is intended for use with an inverted-type metallurgical microscope, appears to have certain limitations—for instance it has no mechanism for bringing each facet of a fracture surface into a position corresponding with the centre of rotation ; hence defocussing, accompanied by lateral displacement of the microscope image, may take place when adjustments to the orientation are made, unless the specimen has previously been set up in the plasticine cup with the particular facet being examined at or very close to the centre of rotation.

The fractographic stage seems most suitable for small specimens comprising relatively few facets not deviating greatly from a mean orientation ; it would be less satisfactory for the examination of larger specimens, or of fractures with facets showing major differences of orientation.

Universal stages designed for use with upright polarizing mineralogical microscopes have been widely employed since first invented by Amici (1844)[1] and subsequently developed by Federov (1893).[2] Mineralogical stages are capable of orientating any desired plane of a selected mineral crystal in a vertical position, and of rotating the crystal so that all directions in the plane pass successively into line with the microscope axis ; such stages may incorporate from two up to five axes of rotation (refer Emmons (1943)).[3]

In general, such stages are intended for the examination of transparent sections in transmitted light. A two-axis mineralogical stage designed for the examination of massive ore specimens in reflected light was described recently by Ehrenberg (1950)[5] ; Ehrenberg's design, however, is intended for the examination of ground surfaces and would not be suitable for the examination of irregular fracture surfaces.

Since no precision universal stage suitable for the microscopical examination of irregular fracture surfaces of reasonable size appears to have been described previously in the literature, the following account of the design and operation of such a device is offered in the hope that it may prove of interest to metallurgists and others engaged in the study of fractures and of the fracture process.

General Considerations Affecting the Design

It was decided first to design the universal stage for use with an upright rather than with an inverted microscope, since, in addition to generally greater convenience in operation of the stage, an upright microscope allows the spot of light focussed by the objective on the fracture surface to be readily observed, thus facilitating the selection of particular facets.

It was considered also that the stage should comply with the following requirements :

(1) It should permit the complete examination of fracture surfaces up to 1 in. diameter and accommodate specimens up to $\frac{3}{4}$ in. maximum thickness.
(2) It should be capable of aligning, normal to the microscope axis, facets of widely differing orientation.
(3) No appreciable defocussing and no lateral displacement of the microscope image should occur during orientation.

Requirement (3) implies that the axes of the various rotations necessary to bring a selected facet into the " level " position must intersect at the focus of the microscope objective. The stage must therefore be capable of being set up on the microscope so that the objective is in focus at the point of intersection of the rotation axes ; it is then necessary to be able to bring any facet of the fracture surface up to this point of intersection of the optical and rotation axes, and hence into focus on the microscope. Thus, as well as requiring traversing movements to enable the full area of the specimen to be examined, it is also necessary for the universal stage to incorporate a specimen elevating movement capable of being used for focussing purposes.

With regard to possible orientation mechanisms, it can be proved geometrically that an elementary plane may be given any desired slope by two rotations about any pair of mutually perpendicular axes fixed in space ; a mechanism complying with these conditions would have certain advantages but would offer difficulties in design and construction.

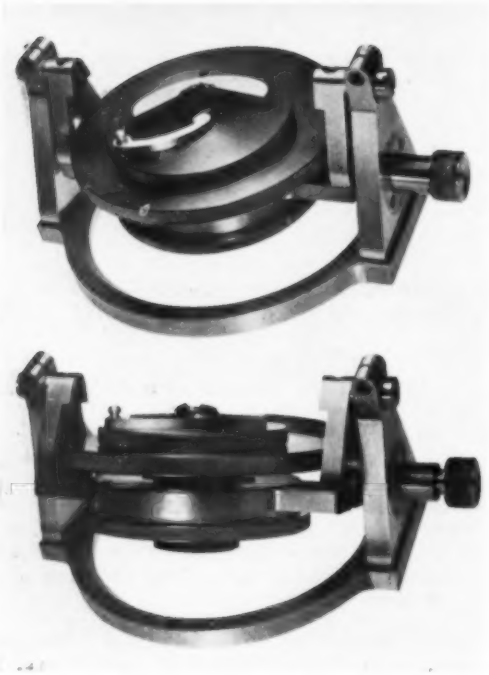


Fig. 1.—Views of the stage from two aspects.

Provided, however, that one of the axes of rotation is fixed exactly in the orientation to which the elementary plane is required to be brought, it can be shown that rotation about this axis, and about a second axis perpendicular to the first but fixed relative to the elementary plane, will enable the plane to be brought to the required slope. The latter conditions are met by two-axis gymbal mountings, and by tilting and revolving tables.

The combination of tilting and revolving movements is employed in the universal stages referred to previously, and represents the most convenient orientating mechanism available; it was decided, therefore, to employ this system of orientation in the present design.

Whereas in mineralogical stages the revolving movement is obtained through a bearing comprising two concentric rings located at the same level as the tilting axis, the use of such a bearing in the present case would adversely affect the convenience of operation of the traversing movement. It was considered, therefore, that the bearing for rotation should be located below the level of the specimen, so as to leave the upper surface of the stage completely unobstructed.

In general, the aim was to design a stage having a minimum number of control knobs and as simple to operate as possible; it was decided, however, to provide certain adjustments for the more critical dimensional settings, so as to reduce the amount of precision machining required and to permit compensation for wear.

Description of the Stage

Fig. 1 is a photograph showing the stage from two different aspects, and Fig. 2 is an assembly drawing to which the following description should be referred.

The stage comprises a base (*A*) which can be attached to the microscope stage by means of two cheese-headed screws, which permit slight lateral movement of the base for centring purposes. The outer brackets (*B*) attached to the base provide adjustable bearings for the tilting movement. The tilting brackets (*C*) support a cross member (*D*) in which is located a Hoffman Type S12 ball-race (*E*), which provides for substantially frictionless rotation of the circular knurled nut (*F*). Play in the ball-race is taken up by means of grub screws which exert pressure on a fabricated thrust-race, which contains sixty $\frac{1}{16}$ in. diameter ball-bearings and bears against the nut. Operation of this nut raises or lowers the cylindrical keyed screw (*G*) in which the boss of the rotating table (*H*) is free both to revolve and to slide axially; the upper end of screw *G* is flanged to support the rotating table. The boss of the rotating table and the bore of the screw are accurately machined with a clearance not exceeding 0·00015 in.; this provides a bearing which, when lubricated with a medium grade of oil, allows sufficiently free rotation of table *H* for convenient operation, but will not permit the table to revolve under the weight of the specimen when the latter is eccentrically disposed and the table tilted. The cylindrical screw is machined with a precision thread of 40 t.p.i.

The rotating table is recessed to accommodate a ground steel plate (*I*) which is screwed to the bottom of specimen table *J*. The clearance between the steel plate and the top and bottom internal surfaces of the rotating table is 0·001 in., and this space is filled by a film of silicone grease, the viscosity of which is substantially unaffected by moderate changes of temperature. Specimen table *J* can thus be slid around on a grease film over a large area of the rotating table, to enable the surface of the specimen to be traversed by the microscope.

For purposes of photography, however, it is important that the sliding movement should not be too free, as the specimen table must not creep, even when carrying a heavy specimen in the tilted position. The incorporation of a neoprene O-ring of 0·002 in. greater thickness than that of the recess in the rotating table has been found to be a most satisfactory means of increasing the friction sufficiently to eliminate all traces of creep: the O-ring has no adverse effect on the smoothness of the sliding movement.

The specimen table is provided with a spring loaded arm (*K*) and a swivelling vee-piece (*L*) with a central spigot which pegs into one of three radially disposed holes according to the size of specimen to be examined. The specimen, irrespective of its shape, can thus be held firmly between the spring loaded arm and the vee-piece without resort to attachment materials, such as plasticine, and it has no tendency to move on the table when the latter is tilted or rotated.

One of the outer brackets (*B*) is fitted with a retractable pin (*M*) which engages with a slot between two hardened steel plates set in the end face of cross member *D*, so as to lock the table in the horizontal position. The eccentric (*N*) affords a means of adjusting the position of the pin, and can be clamped at the correct setting by means of two screws.

The maximum extent to which the specimen table can be raised, either by means of the focussing nut or by sliding up in its bearing, is regulated by means of two adjustable stops (*O*) located in the top portion of the tilting brackets. These stops are set during construction of the stage in such a position that when the rotating table is raised against them, the upper surface of specimen table *J* coincides exactly with the position of

the tilting axis; the stops should rarely require adjustment.

The base, brackets and cross-member are of aluminium alloy; stainless steel is used for the rotating and specimen tables and for the focussing nut, so as to obtain best possible colour match with the aluminium alloy parts. The stage weighs approximately 1·7 lb.

Checking the Adjustments and Centring the Stage

When the universal stage is first set up on the microscope, the following three adjustments should be checked:

(1) The setting of the locking pin eccentric should be such that, when the tilting movement is locked, the rotating table is normal to the optical axis of the microscope.

(2) The axis of rotation must be in line with the optical axis, i.e., the stage must be accurately centred under the microscope.

(3) The setting of the stops in the tilting brackets must be correct.

The setting of the locking pin is checked by first loosening the screws which clamp the eccentric, then, with the universal stage approximately centred, the specimen table is screwed down to a low position and the microscope is focussed on to some recognizable feature on its surface, this datum is brought to the centre of the eye-piece by lateral movement of the specimen table. The rotating table is then slid up to the maximum extent and the microscope refocussed on the specimen table. If the datum-mark is then either forward of or behind the centre of the eye-piece field, the eccentric is revolved until no fore and aft displacement occurs on raising the table.

Sideways displacement of the datum-mark on raising the table indicates that the stage of the microscope itself is not exactly normal to the optical axis. This condition requires rectification by suitable adjustment of the microscope, or else by the insertion of a shim under one side of the base of the universal stage.

After the locking pin has been set in the correct position and the eccentric clamped, the universal stage can then be centred, regardless of the vertical location of the specimen table. The tilting movement is locked, the microscope is focussed on the specimen table and the rotating table is revolved; the centre of rotation is then brought to the centre of the eyepiece field by lateral movement of the universal stage and the cheese-headed screws attaching it to the microscope are then tightened.

As indicated previously, the stops in the tilting brackets are adjusted during construction of the stage and should not require frequent readjustment. The correctness of their setting can be checked, however, by raising the rotating table against the stops and focussing on to the surface of the specimen table. If the stops are in correct adjustment, then a central band in the eyepiece field will remain in focus, and will show no movement when the table is rocked about the tilting axis.

Using the Stage

After being checked for adjustment and centred, the stage is ready for use.

With the tilting movement still locked, the rotating table is slid up against the stops and the microscope is focussed on to the top surface of the specimen table. In this position, the point of focus of the objective coincides

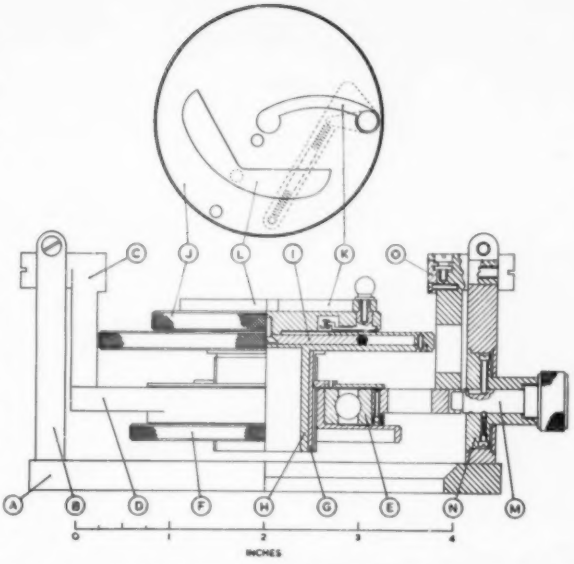


Fig. 2.—Drawing showing constructional details of the stage.

with the point of intersection of the two axes of tilt and rotation. The table is then returned to the operating position against the top of the cylindrical screw; the locking pin is withdrawn and the specimen is placed in position on the specimen table. Subsequently, focussing of the specimen must be carried out by means of the focussing adjustment of the universal stage, and not by means of the microscope focussing controls.

The specimen is traversed by lateral movement of the specimen table and, by means of the focussing nut, facets of interest are brought into such a position that a portion of the facet is in focus near the centre of the eyepiece field. The tilting and revolving movements are then used to bring the facet into the horizontal position, so that the maximum possible area of the eyepiece field is in focus.

For the great majority of facets, once the position of the microscope objective relative to the stage has been set, it is not necessary to touch the focussing controls of the microscope. For facets which require extreme degrees of tilting to bring them into the level position, however, the focussing movement of the universal stage acquires a large lateral component, and has a very small vertical or focussing component, so that there may then be some advantage in using the fine focussing control of the microscope for final focus of the image. If this is done, the point of focus of the objective will no longer coincide with the point of intersection of the rotation axes. It is a simple matter, however, to re-set the focus—the specimen table is merely pushed to one side so as to bring an unobstructed portion of the table surface under the objective, the rotating table is slid up against the stops, and the specimen table surface is again brought into focus by means of the microscope focussing controls. The rotating table is then returned to its operating position and the specimen is brought back under the objective.

It will be apparent that the full potentialities of the universal stage can only be realized if the working distance of the microscope objective is adequate; a refracting objective of 11 mm. focal length probably

represents the highest magnification objective which can conveniently be employed. In many instances, however, it is possible to level a particular facet under a low power long working distance objective, and then to change to a higher powered objective of shorter working distance to obtain increased magnification. If the latter objective is not parfocal with the first, this procedure will of course necessitate use of the focussing controls of the microscope in order to bring the facet into focus at the higher magnification. It will then be necessary, after reverting to the original objective, to re-set the focus as described previously.

Reflecting objectives appreciably increase the magnification at which the stage can normally be operated, although the larger diameter of most commercially available reflecting objectives offsets some of the advantage of their greater working distance. A 2 mm. (4 mm. working distance) reflecting objective with a conical nose, specially designed and constructed at D.S.I., has enabled the stage to be used in the normal manner for examination of fractures at a magnification × 750

Acknowledgments

The assistance and advice of Mr. R. J. Howie, who constructed the stage and made many suggestions incorporated in the design, is acknowledged. This paper is published by permission of the Chief Scientist, Department of Supply, Australia.

REFERENCES

1 Amici, G. B. *Ann. Chim. Phys.*, ser 3, **12**, 114 (1844).
2 Federov, E. S. *Zeits. Kryst. Min.*, **21-22**, (1893-94) **26**, 241 (1896).
3 Emmons, R. C. "The Universal Stage," *Geol. Soc. of Amer. Mem.*, 8 (1943).
4 Zapffe, C. A. and Worden, C. A. *Acta Cryst.*, **2**, 377 (1949).
5 Ehrenberg, H. *Zeits. Erz. u. Metall.*, **3**, 65 (March 1950).

A New Film on Carbide Tools

THE Wimet Division of the Wickman Organisation have always regarded workshop personnel education as one of their most important promotional activities. It has been their consistent policy, therefore, to make available to tool users a wealth of instructional literature on the subject of carbide tool application, as well as a variety of visual aids for the use of lecturers, such as 16 mm. sound films, film strips and lantern slides.

A new film has now been added to the series, with the title "Designing and Applying Carbide Tools." This film, which runs for 35 minutes, has a spoken commentary and covers the subject under four broad headings :—

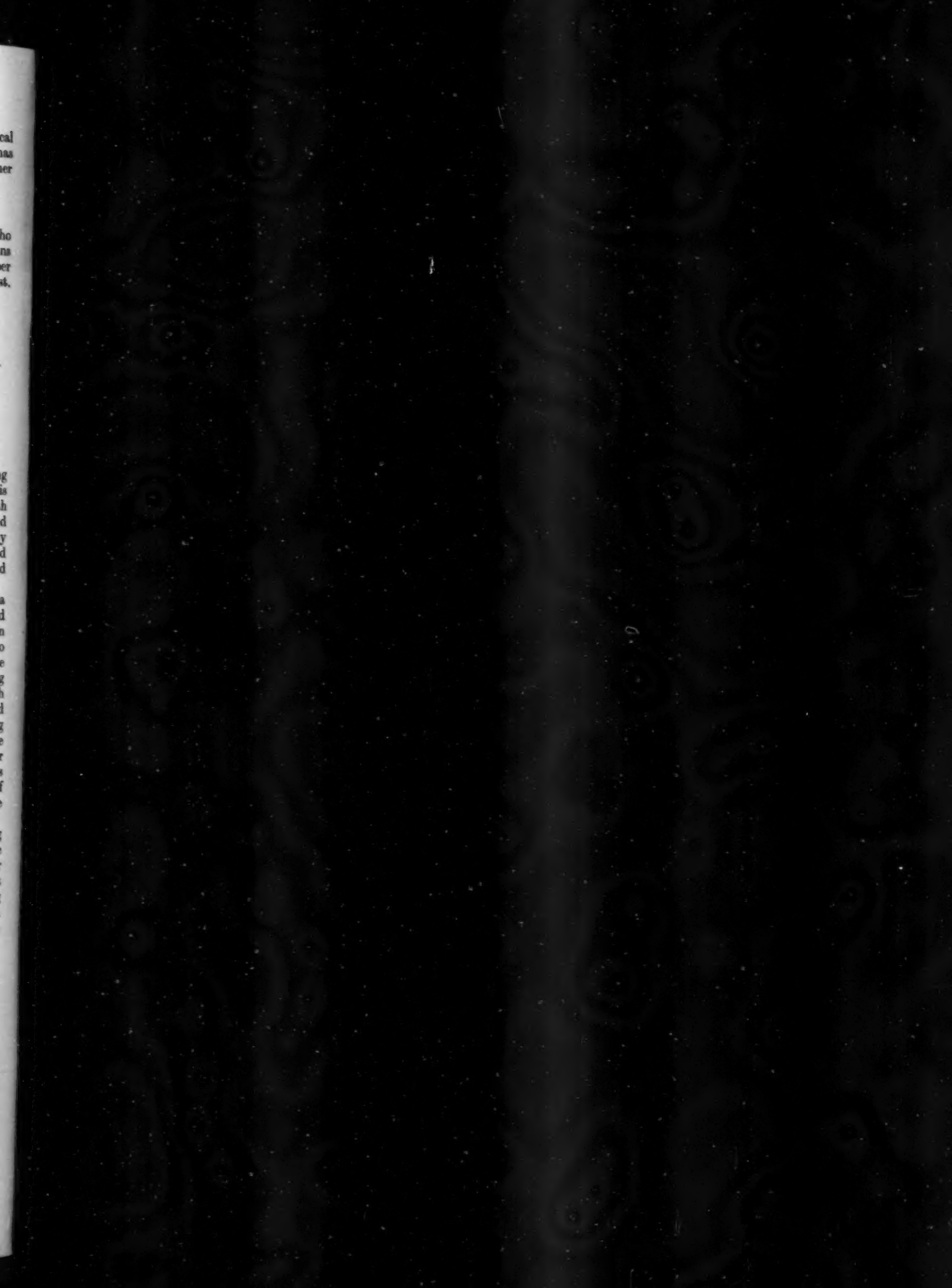
(1) The functional relationship between single point tools, and milling cutters, drills and reamers.
(2) Tool design and terminology.
(3) Factors affecting tool design.
(4) Factors affecting tool application.

The first section, dealing with the functional relationship between various types of tools, illustrates by animated figures how the characteristic geometrical features of the simple lathe tool are also embodied in the design of drills, reamers and milling cutters, and similar tools. The authors have obviously wisely considered that once this basic fact has been appreciated by machine shop personnel, some of the complexities associated with the design of cutting tools will be removed, and a proper understanding of the true functions of tool geometry promoted. For example, the film discusses how direction of feed (along the axis of the work for turning and milling, and through the axis of the tool when drilling and reaming) is related to the design of tools. It goes on to illustrate this by showing the development of a milling cutter from a group of single point tools, and the development of drills and reamers from a boring bar. The film then clearly shows how rake angles and clearances have the same function on any type of tool, but always related to the direction of feed.

This is logically followed by the second section of the film devoted to tool design and terminology. In this section, tool geometry is analysed and clearly illustrated, and terminology explained. The factors affecting tool design, namely the machinability of the material, workpiece condition and ultimate job requirements, as well as power available, are examined in the following section. Here, the influence of cutting pressure is examined in relation to its effect on tool geometry, with particular reference to cutting rake, approach angle, and front to back angle. The film also shows the similarity in function between these tool features on lathe tools and the comparable angles on milling cutters, drills and reamers.

The last section, devoted to application, comprises a valuable contribution to carbide tooling technology, and by the use of a wealth of animated diagrams conveys in a clear and simple manner the basic factors leading to the successful and profitable employment of carbide tools. The factors affecting the selection of cutting speed and feed and the influence of power on the depth of cut, and therefore the metal removal rate, are analysed and illustrated with examples of turning and milling operations. There is a particularly useful sequence devoted to the establishment of metal-working data for all types of operations, which, together with the lessons drawn in the earlier parts of the film, should prove of high educational value to students and machine operators.

The Company have also produced a booklet containing the information covered by the film and some of the diagrams, which it is intended should be retained for reference purposes after the film has been seen. It carries the title of the film, "Designing and Applying Carbide Tools" and can be obtained from Wickman Ltd., Publicity Department, Coventry, to whom application for the loan of films should also be addressed.

Honeywell-Brown Open Belfast Office

To meet N. Ireland's accelerating demand for instrumentation, the U.K. associates of the International Honeywell organisation have opened a Branch Office in Belfast. Under the supervision of MR. W. J. EDWARDS, the new branch offers expert assistance with the choice, installation, and maintenance of the Company's industrial instrumentation, precision snap action switches, and automatic controls for heating and air conditioning systems. All enquiries should be addressed to Mr. W. J. Edwards, Honeywell-Brown, Ltd., 123, Cumberland Road, Dundonald, Belfast.